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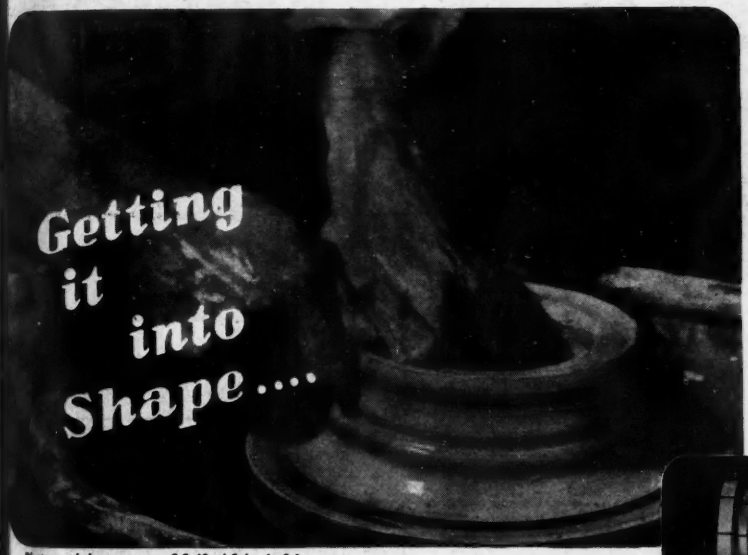

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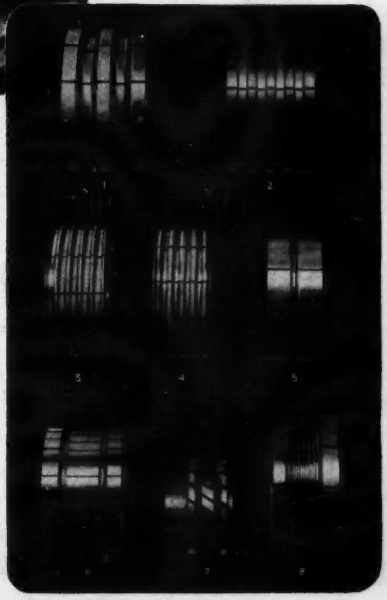
1. **Steering Worm.**
2. **Acme Thread.**
3 & 4. **Ball Thread.**
5. **Special Acme Thread.**
6. **Valve Seat Inserts.**
7. **Reduction Gear Tooth Form.**
8. **"Jet" Propulsion Blade Root.**



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THEORETICAL NOTES ON SOME JET PROPULSION ENGINES

By K. R. SCHEUTER. (From *Flugwehr und-Technik*, Vol. 8, No. 11, November, 1946, pp. 290-295 and No. 12, December, 1946, pp. 318-323.)

NOMENCLATURE AND DEFINITIONS.

$w_{1\cdots n}$ $T_{1\cdots n}$ Velocities in direction of flight and co-ordinated temperatures ; index relates to location

w_1, T_1 Air speed and temperature (I.C.A.N.)

$w_2 = \alpha \,.\, w_1 = \varphi \,.\, Mu_a \,.\, a_1 \sqrt{\mathfrak{M}}$ Velocity at compressor inlet

$a_{1\cdots n} = \sqrt{g\,k\,R\,T_{1\cdots n}}$ Speed of sound, e.g.

a_1 Speed of sound in outer air

a_2 Speed of sound at inlet to the first stage of compressor or outlet of intake diffusor

$p_{1\cdots n}$ Appropriate pressures

$$\mathfrak{M} = \frac{T_2}{T_1} = \frac{1 + \dfrac{k-1}{2} M_1^2}{1 + \dfrac{k-1}{2} \varphi^2 Mu_{a2}}$$

Adiabatic temperature ratio = of ram pressure at the intake diffusor

$$\varphi = \frac{c_m}{u_a} = \frac{w_2}{u_a}$$ Speed ratio of the first stage of compressor

$$Mu_a = \frac{u_a}{a_2}$$ Mach number relating to the peripheral velocity of the first stage of compressor

$$\delta = \frac{T_3}{T_2} = \left(\frac{p_3}{p_2}\right)^{\frac{k-1}{k}}$$ Adiabatic temperature ratio of compressor

$$\phi = 1 - \frac{1}{\delta \,.\, \mathfrak{M}}$$

η_V Efficiency of intake diffusor

η_K Efficiency of compressor

$$\epsilon = \frac{\Delta p}{p}$$ Pressure loss coefficient of combustion chamber

η_B Efficiency of combustion

η_T Efficiency of turbine

η_R Efficiency of jet pipe

η_P Efficiency of propeller

$c_p = 0{\cdot}24 \dfrac{\text{kcal}}{\text{kg . degree}} = \text{const.}$ Specific heat of air

Instead of the efficiency, often the fuel consumption per hour b (kg./kg. . hr. or lb./lb. hr.) per unit thrust is of interest.

We have $b = 3{,}600 \dfrac{Q}{H_u \,.\, S}$ (kg./kg. . hr.)

where Q is the heat absorbed, H_u the lower calorific value, and S the thrust. With the efficiency

$$\eta = \frac{A \,.\, S \,.\, w_1}{Q},$$

we have $b = 3{,}600 \dfrac{A \,.\, w_1}{\eta \,.\, H_u}$

Substituting for $A = \dfrac{1}{427} \dfrac{\text{kcal}}{\text{mkg}}$ and $H_u = 10^4 \dfrac{\text{kcal}}{\text{kg}}$

we obtain $b = 0{\cdot}843 \,.\, 10^{-3} \dfrac{w_1}{\eta}$ (kg./kg. hr.)

THE ATHODYD OR RAM-JET.

The athodyd (Fig. 1) consists of a diffusor in which the air speed w_1 is decelerated to $w_2 = \alpha\, w_1$, of a combustion chamber where the air is heated, at approximately constant pressure, from $T_2 = \mathfrak{M}\, T_1$ to $T_3 = K \,.\, T_1$, and of a jet pipe in which the air is expanding to the outer air pressure p_1 and temperature T_4''.

As the calculations are the same as in previous publications[1, 2], the results will be stated only.

We have for the efficiency ($\eta_E = 1$ assumed)

$$\eta = \frac{2\eta_B \sqrt{\dfrac{k-1}{2} M_1^2}}{K - \mathfrak{M}} \underbrace{\left\{ \sqrt{\left(1 - \frac{\xi}{\mathfrak{M}}\right) K + \frac{k-1}{2} \alpha^2 M_1^2} - \sqrt{\frac{k-1}{2} M_1^2} \right\}}_{R} \quad (1)$$

$$\eta = \frac{2\eta_B R}{K - \mathfrak{M}} \quad (2)$$

where $\xi = \left(\dfrac{1}{1-\epsilon}\right)^{\frac{k-1}{k}}$ is taking into account the total pressure loss.

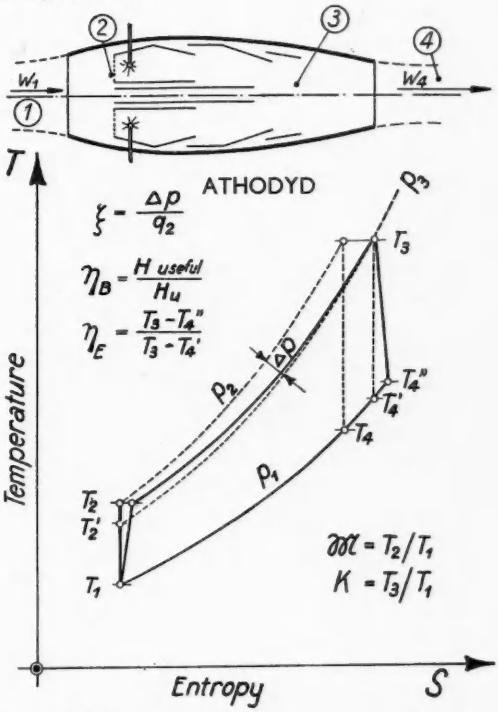


Fig. 1. Arrangement and entropy chart of the athodyd.

1. T. ACHERET, THE ENGINEERS' DIGEST, Vol. 5, No. 8, August, 1944, pp. 221-223.
2. K. SCHEUTER, THE ENGINEERS' DIGEST, Vol. 7, No. 5, May, 1946, pp. 124-128.

Relating the pressure loss to the local dynamic pressure $q_2 = \frac{\rho_2}{2} \cdot \alpha^2 \cdot w_1^2$, we have with $\zeta = \frac{\Delta p}{q_2}$

$$\epsilon = \frac{\Delta p}{p_2} = \zeta \frac{k \cdot \alpha^2 M_1^2}{2\mathfrak{M}} \quad .. \quad .. \quad (3)$$

The efficiency is independent of the altitude.

The thrust is given by

$$S = \rho_1 a_1^2 F_2 \mathfrak{M}^{\frac{1}{k-1}} \alpha \cdot M_1 \sqrt{\frac{2}{k-1}} \left\{ \sqrt{R} - \sqrt{\frac{k-1}{2} M_1^2} \right\} \quad (4)$$

In this equation $\rho_1 a_1^2$ only is dependent on the altitude. The factor F_2 (cross sectional area of flow before combustion takes place) is a measure for the absolute size of the propulsion unit. It is therefore useful to introduce a dimensionless thrust coefficient, defined by

$$\sigma = \frac{S}{\frac{\rho_1}{2} a_1^2 \cdot F_2} \quad .. \quad .. \quad (5)$$

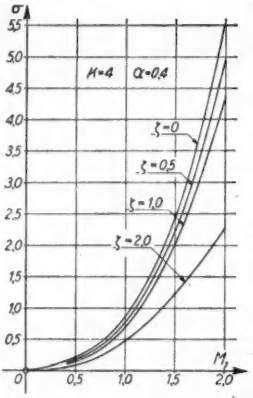


Diagram 1. Thrust coefficient of athodyd for $\alpha = 0{\cdot}4$; $K = 4$.

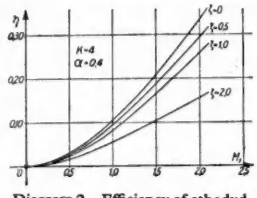


Diagram 2. Efficiency of athodyd for $\alpha = 0{\cdot}4$; $K = 4$.

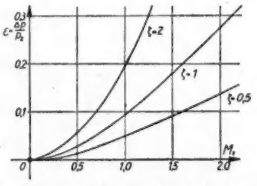


Diagram 3. Pressure loss related to the absolute theoretical pressure in the combustion chamber for $\alpha = 0{\cdot}4$.

The variation of the parameters involved is shown in a series of diagrams. As can be seen from Diagrams 1 and 2, both σ and η increase parabolically with increasing Mach number M_1. This increase takes place until the ram temperature reaches the value T_3. For $T_2 = T_3$, i.e. when there is no further increase in heat, the thrust becomes zero if the process takes place without losses ; but if losses occur, a negative thrust or resistance will be present. The pressure loss even at high speeds can be permitted up to $\zeta = 1$. As shown in Diagram 3, the pressure loss, in relation to the absolute pressure, is considerable.

As there is no static thrust, an aircraft fitted with an athodyd requires a take-off aid.

In Diagrams 1 and 2, $\alpha = 0{\cdot}4 = \text{const.}$ has been assumed. In reality, the maximum value of w_2 will be determined by the process of combustion, where α varies with M_1. As with increasing M_1 α decreases. the efficiency increases (see Diagr. 4), while the thrust coefficient decreases, because even for small velocities ($M_1 = 0{\cdot}6$ to $0{\cdot}8$) $\alpha < \alpha_{optimum}$. As Diagram 5 shows, the thrust coefficient increases with $K = T_3/T_1$ almost linearly, whereby $\sigma = 0$ for a minimum value of K which is defined by the heat supplied to the combustion chamber necessary to cover the losses. The efficiency is a maximum at relatively small K, which value is increasing with increasing losses. In the case of zero losses, we have $K_{opt} = K_{min} = \mathfrak{M}$.

In conclusion it may be stated that

1. The athodyd, not yielding static thrust, requires take-off aid for the aircraft.
2. The efficiency is high at supersonic speeds only.
3. At such speeds considerable thrusts can be expected.

THE GAS TURBINE-JET.

Let us consider the well known turbine engine and take pressure losses into account, and also losses due to incomplete combustion of the fuel burned. The latter is being taken care of by introducing an efficiency of combustion η_E.

The overall efficiency is then:

$$\eta = \frac{2\eta_E \sqrt{\frac{k-1}{2} M_1^2}}{K - \mathfrak{M}\left(1 + \frac{\delta - 1}{\eta_K}\right)} \left\{ \sqrt{\eta_E} \sqrt{R} - \sqrt{\frac{k-1}{2} M_1^2} \right\} \quad (6)$$

where

$$R = \frac{K - \mathfrak{M} \frac{\delta - 1}{\eta_K}}{K - \mathfrak{M} \frac{\delta - 1}{\eta_K \eta_T}} \left\{ K\left(1 - \frac{\xi}{\delta\,[1 + \eta_F(\mathfrak{M} - 1)]}\right) - \mathfrak{M} \frac{\delta - 1}{\eta_K \eta_T} \right\} + \frac{k-1}{2} \varphi^2 M_{u_a}^2 \mathfrak{M} \quad (7)$$

and the thrust coefficient

$$\sigma = \frac{S}{\frac{\rho_1}{2} a_1^2 F_K} = 2\mathfrak{M}^{\frac{k+1}{2(k-1)}} \varphi \cdot M_{u_a} \sqrt{\frac{2}{k-1}} \left\{ \sqrt{\eta_E} \sqrt{R} - \sqrt{\frac{k-1}{2} M_1^2} \right\} \quad (8)$$

It proposed to show first how the thrust coefficient and the efficiency of the turbine-jet vary with the parameters M_1, δ, K, and ($\varphi \cdot M_{u_a}$) (of which the latter term corresponds to the value $\alpha = \frac{w_2}{w_1}$ of the previous case).

Diagram 6 affords a good comparison with Diagrams 1 and 2, and shows that at subsonic speeds the turbine-jet is superior to the athodyd as to thrust and efficiency. At considerably higher speeds, i.e. when the ram effect becomes comparable to, or even exceeds, the pressure ratio of the compressor, the athodyd may give slightly better results than the turbine-jet as compressor and turbine losses are absent. Moreover, the small weight and mechanical simplicity of the athodyd are a further advantage. The turbine-jet, however, produces a static thrust which approximately equals the thrust at $M_1 = 0{\cdot}7$ to $0{\cdot}8$.

So with increasing speed (i.e. with increasing $\mathfrak{M}$) and increasing pressure ratio of the compressor (i.e. with increasing δ) the heat supplied in the combustion chamber

$$Q = c_p T_1 \left\{ K - \mathfrak{M}\left(1 + \frac{\delta - 1}{\eta_K}\right) \right\} \left(\frac{\text{k. cal.}}{\text{kg. sec.}}\right) \quad (9)$$

decreases, the thrust and efficiency must ultimately become zero. For a given value of M_1, σ and η will have maxima at various values of δ. When selecting a

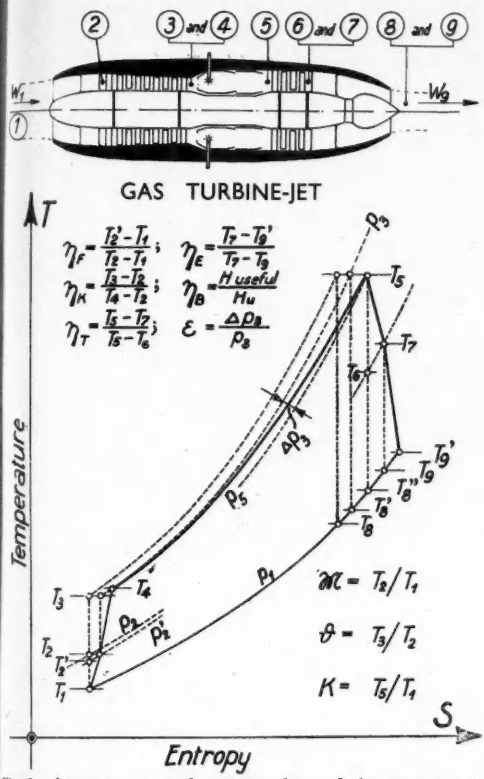


Fig. 2. **Arrangement and entropy chart of the pure gas turbine engine.**

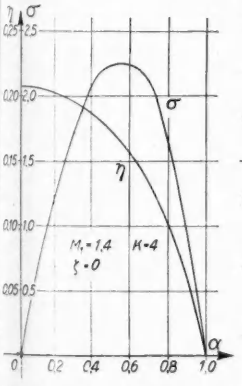


Diagram 4. Thrust coefficient and efficiency as a function of α.

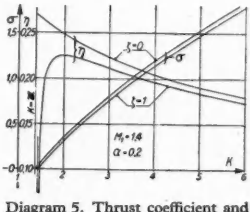


Diagram 5. Thrust coefficient and efficiency as a function of K.

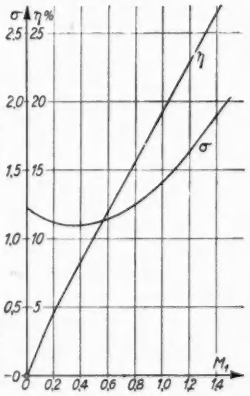


Diagram 6. Thrust coefficient and efficiency of a turbine-jet as a function of the Mach number ($\delta = 1.45$; $\varphi \cdot Mu_a = 0.4$; $K = 4$; $\eta_F = 0.95$; $\eta_K = 0.85$; $\varepsilon = 0.05$; $\eta_T = 0.90$; $\eta_E = 0.95$; $\eta_B = 0.95$).

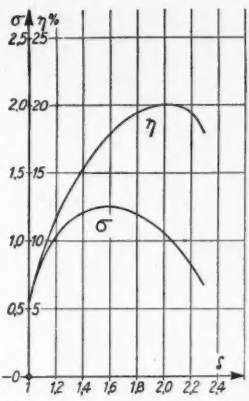


Diagram 7. Thrust coefficient and efficiency as a function of the adiabatic temperature ratio δ ($M_1 = 0.75$; $\varphi \cdot Mu_a = 0.4$; $K = 4$; $\eta_K = 0.80$; $\eta_T = 0.85$).

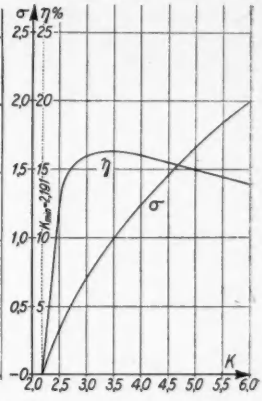


Diagram 8. Thrust coefficient and efficiency as a function of K ($M_1 = 0.75$; $\delta = 1.45$; $\varphi \cdot Mu_a = 0.4$ $\eta_K = 0.80$; $\eta_T = 0.85$).

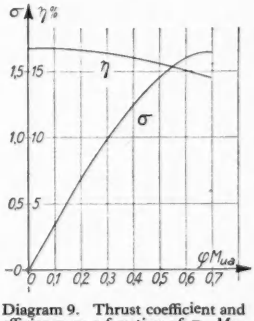


Diagram 9. Thrust coefficient and efficiency as a function of $\varphi \cdot Mu_a$ ($M_1 = 0.75$; $\delta = 1.45$; $K = 4$; $\eta_K = 0.80$; $\eta_T = 0.85$).

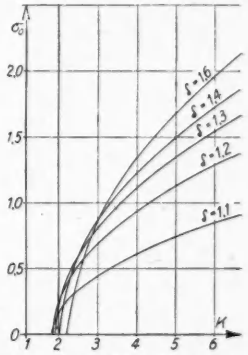


Diagram 10. Static thrust as function of K ($\varphi \cdot Mu_a = 0.42$; $\eta_K = 0.8$; $\eta_T = 0.85$).

suitable value for δ the choice will obviously fall to a δ between these two optimum values. This requires pressure ratios not encountered at present.

The influence of the maximum temperature $T_5 = KT_1$ in front of the turbine is similar to that on the athodyd (Diagram 8).

The amount of air flowing through the turbine engine is

$$G = \rho_2 \cdot g \cdot w_2 F_K = \rho_1 g \mathfrak{M}_1^{\frac{k+1}{2(k-1)}} \varphi \cdot Mu_a \cdot a_1 F_K \quad (10)$$

i.e. it is proportional to $(\varphi \cdot Mu_a)$. With increasing $(\varphi \cdot Mu_a)$ the ram effect decreases, and, therefore, the efficiency is lowered. The thrust coefficient increases rapidly and almost linearly with $(\varphi \cdot Mu_a)$. As the compressor weight for a given number of stages is in first approximation inversely proportional to σ, from the weight point of view an increase of $(\varphi \cdot Mu_a)$ does pay even at a loss of efficiency (Diagram 9).

The variation of static thrust with K and δ is shown in Diagram 10.

Having dealt with the general issues, it will be necessary to investigate more closely the influence of the part efficiencies and the pressure loss in the combustion chamber.

To this end, a normal duty point has been assumed characterized by the following data :

$M_1 = 0.75$; $\delta = 1.45$ ($P_3/P_2 \simeq 3.67$) ; $\varphi \cdot Mu_a = 0.4$;

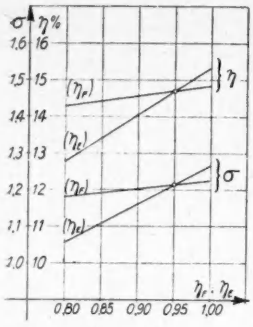


Diagram 11

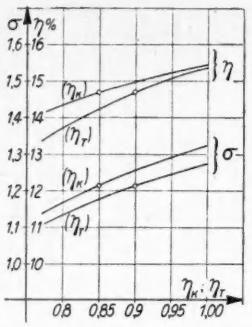


Diagram 12

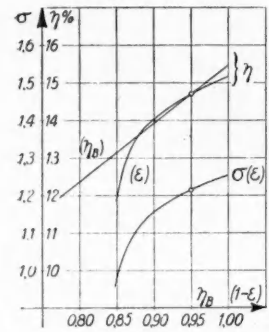


Diagram 13

Diagram 11. The influence of the part efficiencies η_F and η_E.

Diagram 12. The influence of the part efficiencies η_K and η_T.

Diagram 13. The influence of efficiency η_B and of the pressure loss ϵ.

$K = 4$; $\eta_F = 0{\cdot}95$; $\eta_K = 0{\cdot}85$; $\epsilon = 0{\cdot}05$; $\eta_B = 0{\cdot}95$; $\eta_T = 0{\cdot}90$; $\eta_E = 0{\cdot}95$.

Hereby, the overall efficiency is $\eta = 0{\cdot}147$ and the thrust coefficient $\sigma = 1{\cdot}214$.

Only one part efficiency has been considered at a time as a variable[3], the rest being kept constant (Diagrams 11 to 13). These diagrams show at a glance that of all losses, the pressure loss and those due to incomplete combustion are the largest.

The conclusions can be summarized as :

1. The gas turbine engine is best suited for high speed aircraft as the efficiency is increasing with speed.
2. The pressure ratio of the compressor should be as great as possible.
3. Special consideration should be given to the losses due to the combustion chamber.
4. The product $(\varphi \,.\, Mu_a)$ should be great, i.e. a large quantity of air should pass through the compressor.

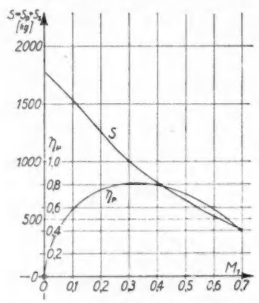


Diagram 14. Total thrust and propeller efficiency of a gas turbine-propeller unit.

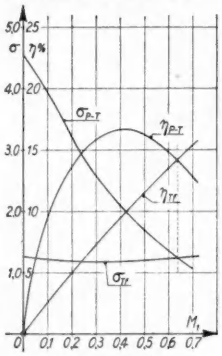


Diagram 15 (right). Comparison of a gas turbine-propeller unit with a pure turbine-jet.

3. The necessary calculations were done by Z. PLASKOWSKI.

Diagram 14 is based on the following details: Shaft horsepower $N_{pf} = 1{,}800$ h.p. for $M_f = 0{\cdot}6$; $H = 0$; $\varphi \,.\, Mu_a = 0{\cdot}42$; $\delta = 1{\cdot}5$ $K = 4$; $\eta_K = 0{\cdot}8$; $\eta_T = 0{\cdot}85$; $\beta = 0{\cdot}9$; $F_K = 0{\cdot}0345\text{m}^2$ $D_K = 0{\cdot}329\text{m}$; $\nu = 0{\cdot}6$ four blade;

Escher-Wyss-Propeller $D_P = 3{\cdot}00$ m. ; $\dfrac{D_P}{D_K} = 9{\cdot}12$.

GAS TURBINE WITH PROPELLER.

From a previous publication[2] we have

$$\alpha = \frac{w_2}{w_1} = \varphi \,.\, \frac{Mu_a}{M_1}\sqrt{\mathfrak{M}} \text{ and } \mathfrak{M} = \frac{1 + \dfrac{k-1}{2} M_1^2}{1 + \dfrac{k-1}{2} \varphi_2 \, Mu_a^2} \quad \ldots (11)$$

$$\eta = \frac{P + 2\sqrt{\dfrac{k-1}{2}} M_1^2 \left\{ \sqrt{R} - \sqrt{\dfrac{k-1}{2}} M_1^2 \right\}}{K - \mathfrak{M}\left(1 + \dfrac{\delta - 1}{\eta_K}\right)} \quad (12)$$

and

$$\sigma = 2\mathfrak{M}^{\frac{k+1}{2(k-1)}} \varphi \,.\, Mu_a \sqrt{\frac{2}{k-1}} \left\{ \frac{P}{2\sqrt{\dfrac{k-1}{2}} M_1^2} + \sqrt{R} - \sqrt{\frac{k-1}{2}} M_1^2 \right\} \quad (13)$$

where

$$P = \eta_P \left(\eta_T \beta K \phi - \mathfrak{M} \frac{\delta - 1}{\eta_K} \right) \quad \ldots (14)$$

$$R = K\phi \frac{1 - \eta_T \beta \phi}{1 - \beta \phi} (1 - \beta) + \frac{k-1}{2} \varphi^2 \, Mu_a^2 \, \mathfrak{M} \quad (15)$$

Strictly speaking, the thrust coefficient σ applies to geometrically similar units only. In particular the ratio propeller diameter to compressor diameter must be kept constant.

To get a complete picture, Diagram 14 shows the propeller efficiency and the total thrust obtained by the gas turbine-propeller combination. As the efficiency curve shows, the propeller is designed for a large static thrust and a good rate of climb.

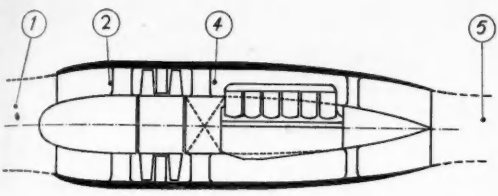
Diagram 15 gives the compression between a gas turbine propeller unit (index $_{P\text{-}T}$) and the pure gas turbine-jet (index $_{T_t}$).

The Mach number at which these two propulsion systems are equivalent is indicated by a dotted line. For lower Mach numbers the gas turbine-propeller unit is superior to the pure gas-turbine-jet, for higher Mach numbers the reverse is true.

THE DUCTED FAN.

The positive drive ducted fan obviates the losses due to compressibility present at the tips of free propellers by virtue of the speed reduction in the inlet diffusor.

Thrust coefficient and efficiency can be derived from the temperature-entropy chart Fig. 3.



THE DUCTED FAN

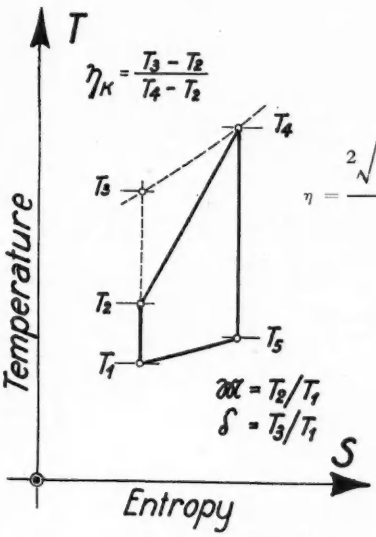


Fig. 3. **Arrangement and entropy chart of a ducted fan without after-burning.**

$$\sigma = 2\,\mathfrak{M}^{\frac{k+1}{2(k-1)}}\,\varphi\,.\,Mu_a\sqrt{\frac{2}{k-1}}\left\{\sqrt{R} - \sqrt{\frac{k-1}{2}M_1^2}\right\} \quad (16)$$

and

$$\eta = \frac{2\,\eta_K\sqrt{\frac{k-1}{2}M_1^2}}{\mathfrak{M}(\delta-1)}\left\{\sqrt{R} - \sqrt{\frac{k-1}{2}M_1^2}\right\} \quad (17)$$

where $R = \left(\mathfrak{M} - \frac{1}{\delta}\right)\left(1 + \frac{\delta-1}{\eta_K}\right) + \frac{k-1}{2}\varphi^2 Mu_a^2\,\mathfrak{M}$ (18)

The overall efficiency is the product of the efficiency of the fan and of the efficiency of the prime mover. The magnitude of the thrust increases due to a ducted fan can be understood when considering that the thrust coefficients of propellers are well below the thrust curve for $\delta = 1{\cdot}02$ in Diagram 16.

The static thrust of the gas turbine propeller unit with the propeller used in the previous chapter for $H = O$ and $D = 3$m. is $S_o = 1{,}510$ kg.

Thus, $\sigma_0 = \dfrac{S_0}{\frac{\rho_1}{2}a_1^2 F_P} = \dfrac{1{,}510}{7{,}140 \times 7{\cdot}07} = 0{\cdot}0299$ as compared with $\sigma_0 = 0{\cdot}237$ of the ducted fan for σ K $1{\cdot}02$. As the efficiency of the ducted fan increases with increasing speed, the ducted fan is superior to the propeller propulsion at high speeds (Diagram 17). When using the ducted fan, it is possible to inject and burn fuel behind the fan.

In this case the thrust coefficient takes the form

$$\sigma = 2\,\mathfrak{M}^{\frac{k+1}{2(k-1)}}\,\varphi\,.\,Mu_a\sqrt{\frac{2}{k-1}}$$

$$\left\{\sqrt{K\phi + \frac{k-1}{2}\varphi^2 Mu_a^2\,\mathfrak{M}} - \sqrt{\frac{k-1}{2}M_1^2}\right\} \quad (19)$$

while the efficiency is given by

$$\eta = \frac{2\sqrt{\frac{k-1}{2}M_1^2}\left\{\sqrt{K\phi + \frac{k-1}{2}\varphi^2 Mu_a^2\,\mathfrak{M}} - \sqrt{\frac{k-1}{2}M_1^2}\right\}}{K - \mathfrak{M}\left\{1 - \frac{1-\eta_M}{\eta_M\,\eta_K}(\delta-1)\right\}} \quad (20)$$

where η_M is the efficiency of the fan drive.

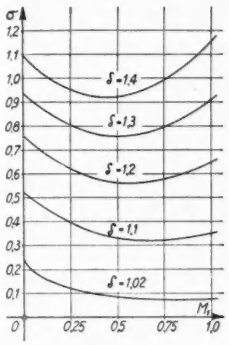


Diagram 16.

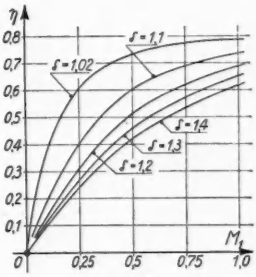


Diagram 17.

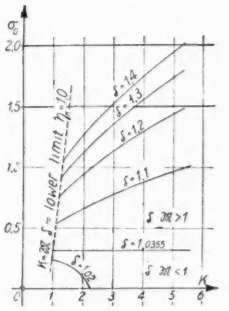


Diagram 18.

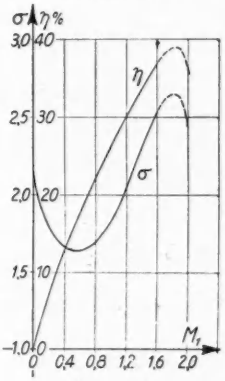


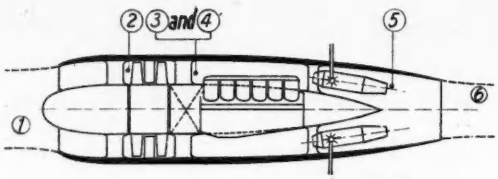
Diagram 19.

Diagram 16. Thrust coefficient of a ducted fan as a function of Mach number for $\varphi\,.\,Mu_a = 0{\cdot}42$; $\eta_K = 0{\cdot}80$.

Diagram 17. Efficiency of a ducted fan. The curves are valid for $0{\cdot}3 < \varphi\,.\,Mu_a < 0{\cdot}5$ ($\eta_K = 0{\cdot}80$).

Diagram 18. Static thrust as a function of $K = \dfrac{T_5}{T_1}$ with after-burning.

Diagram 19. Thrust coefficient and efficiency as a function of M_1. $\varphi\,.\,Mu_a = 0{\cdot}42$; $\delta_1 = 1{\cdot}5$; $K = 4$; $\eta_K = 0{\cdot}85$; $\eta_T = 0{\cdot}90$; $\delta_2 = 1{\cdot}2$; $\eta = 0{\cdot}85$; $A = 1{\cdot}7$.



DUCTED FAN WITH AFTER-BURNING

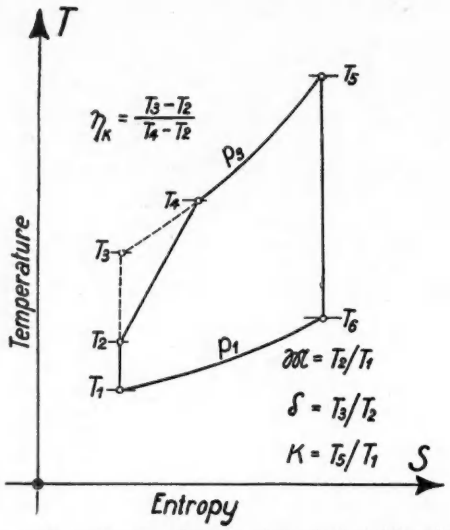


Fig. 4. **Arrangement and entropy chart of a ducted fan with after-burning.**

In order to achieve a thrust increase by after-burning, the pressure behind the fan must be greater than the atmospheric pressure, i.e. $\frac{T_3}{T_1} = \delta \cdot \mathfrak{M} > 1$, so that an expansion of the gases can take place. That this is not always the case, especially not when starting, can be seen from Diagram 18.

CONCLUSIONS.

1. The efficiency of the ducted fan increases with increasing speed.
2. The thrust per unit area can be increased by increasing the pressure ratio.
3. At a sufficiently high pressure ratio, after-burning increases the thrust considerably, but
4. The efficiency decreases rapidly.

GAS TURBINE WITH THRUST AUGMENTOR.

There is a great variety of arrangements of ducted fans, e.g. positive drive ducted fan or a free turbine augmentor ; all these are covered by the same theory.

Such an arrangement is shown in Fig. 5. The power consumed by the ducted fan is supplied by the turbine ; with the quantity of air passing through the fan Λ times greater than that passing through the turbine, we have

$$c_p (T_7 - T_9) = \Lambda\, c_p (\Theta_4 - \Theta_2) \quad .. \quad (21)$$

This interconnection determines also the maximum value Λ. The heat drop ratio $z = \frac{T_6 - T_8}{T_6 - T_{10}}$ cannot be

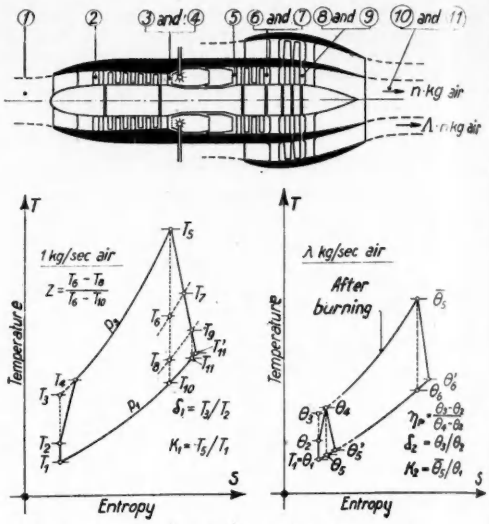


Fig. 5. **Arrangement of a gas turbine with thrust augmentor (ducted fan) and entropy charts for both.**

greater than $z = 1$ (pure gas turbine-jet). Herefrom follows as a limiting condition

$$T_8 = T_{10} \text{ and } \Lambda_{max} = \frac{\frac{\eta_T}{\mathfrak{M}} K\phi - \frac{\delta_1 - 1}{\eta_K}}{\frac{\delta_1 - 1}{\eta_P}} \quad (22)$$

Therefore, we have $z = \frac{\Lambda}{\Lambda_{max}}$ .. .. (23)

The total thrust is

$$s = s_D + s_T \left[\frac{\text{kg.}}{\text{kg./sec.}}\right] \quad .. \quad (24)$$

where s_D = Specific thrust of turbine-jet
s_T = Specific thrust of ducted fan.

The thrust coefficient referred to the compressor cross-sectional area F_K and under the assumption that $\varphi \cdot Mu_a$ is equal for both compressor and fan, can be expressed by

$$\sigma = 2\,\mathfrak{M}^{\frac{k+1}{2(k-1)}} \varphi \cdot Mu_a \sqrt{\frac{2}{k-1}} \left[\left\{ \sqrt{\eta_E} \sqrt{R_D} - \sqrt{\frac{k-1}{2}} M_1^2 \right\} + \Lambda \left\{ \sqrt{\eta_E} \sqrt{R_T} - \sqrt{\frac{k-1}{2}} M_1^2 \right\} \right] \quad (25)$$

where

$$R_D = \frac{K_1 - \mathfrak{M} \left\{ \frac{\delta - 1}{\eta_K} + \Lambda \frac{\delta_2 - 1}{\eta_P} \right\}}{K_1 - \frac{\mathfrak{M}}{\eta_T} \left\{ \frac{\delta_1 - 1}{\eta_K} + \Lambda \frac{\delta_2 - 1}{\eta_P} \right\}} \left\{ K_1 \phi_1 - \frac{\mathfrak{M}}{\eta_T} \left(\frac{\delta_1 - 1}{\eta_K} + \Lambda \frac{\delta_2 - 1}{\eta_K} \right) \right\} + \frac{k-1}{2} \varphi^2 Mu_a^2 \mathfrak{M} \quad (26)$$

and

$$R_T = \left(\mathfrak{M} - \frac{1}{\delta_2}\right)\left(1 + \frac{\delta_2 - 1}{\eta_P}\right) + \frac{k-1}{2}\varphi^2 M u_a^2 \mathfrak{M} \quad (27)$$

if there is no after-burning behind the ducted fan, or

$$R_T = K_2 \phi_2 + \frac{k-1}{2}\varphi^2 M u_a^2 \mathfrak{M} \quad .. \quad (28)$$

with after-burning, when $K_2 = \frac{\overline{\Theta}_5}{\Theta_1}$.

If the thrust coefficient is related to the required total cross-sectional area, we have

$$\sigma^1 = \frac{\sigma}{1 + A} \quad .. \quad .. \quad (29)$$

The efficiency of the unit is then

$$\eta = \frac{2\sqrt{\frac{k-1}{2}M_1^2}\left[\left\{\sqrt{\eta_E}\sqrt{R_D} - \sqrt{\frac{k-1}{2}M_1^2}\right\} + A\left\{\sqrt{\eta_E}\sqrt{R_T} - \sqrt{\frac{k-1}{2}M_1^2}\right\}\right]}{N} \quad (30)$$

Without after-burning

$$N = K_1 - \mathfrak{M}\left(1 + \frac{\delta_1 - 1}{\eta_K}\right) \quad .. \quad (31)$$

and with after-burning

$$N = K_1 - \mathfrak{M}\left(1 + \frac{\delta - 1}{\eta_K}\right) + A\left\{K_2 - \mathfrak{M}\left(1 + \frac{\delta_2 - 1}{\eta_P}\right)\right\} \quad .. \quad (32)$$

Without after-burning the σ and η-curves (Diagram 19) are similar to the pure gas-turbine-jet. However, by decreasing kinetic energy losses in the ducted fan improvements are possible. This of course necessitates an increase of cross-sectional area. For the designer the frontal area of different engines for the same thrust is of importance. Comparing the gas turbine with thrust augmentor to the pure gas-turbine engine (index $_{Tf}$) we have

$$\frac{F}{F_{Tf}} = \frac{(1 + A)\sigma_{Tf}}{\sigma} \quad .. \quad .. \quad (33)$$

After-burning has the same effect as with the free ducted fan. A great thrust increase is bought by a considerable loss in efficiency.

Conclusions for this type of propulsion are :

1. The static thrust of the gas turbine with augmentor is superior to that of the pure gas-turbine jet.

2. In order to improve considerably the efficiency, the amount of air passing through the fan must be great, the optimum pressure ratio being only small.

3. After-burning in the ducted fan increases the thrust considerably but reduces the efficiency.

COPPER PHOSPHIDE FROM A CRUCIBLE

By S. A. YASIK. (From "*Vestnik Mashinostroenia*," No. 2/3, 1946, pp. 75-76, 3 illustrations.)

COPPER phosphide is an extremely important alloying material in a bronze foundry and many works would make more use of it if they could produce it themselves. The author has been experimenting with a view to producing it in the foundry crucible and has found a simple method practicable in the smallest of foundries.

The raw materials are commercial red copper and red phosphorus. The copper is melted in the ordinary way in a crucible under a ventilating funnel and the phosphorus is prepared in paper packets of 2 or 3 ounces, tied with twine and laid out ready for use at a safe distance from the furnaces, the amount to be used being calculated on the basis of 12-14 per cent phosphorus, with an allowance of 25-30 per cent for losses.

The copper is heated under a protective layer of charcoal to a temperature not exceeding 1,150 deg. C., because at higher temperatures too much phosphorus burns away. Then, without removing the crucible from the furnace, the foundryman clears the surface of the copper and introduces the phosphorus by throwing in the paper bags one by one and plunging each bag to the bottom immediately by means of a special tool consisting of an 8 in. dia. inverted hollow hemisphere with a curved handle. The phosphorus is held under by this tool until it boils.

To prevent the iron of the tool from dissolving in the copper, it is coated with a protective layer which must be renewed quite frequently and dried over the furnace flame, and to allow for this each operator should have 3 or 4 of these tools at hand. This coating is made by mixing one part fireclay, 2 parts soapy clay and 0·1 part molasses, with water to the consistency of batter.

RUSSIA

When sufficient phosphorus has been added the metal is covered up with charcoal again, re-heated to 1,120-1,150 deg. C. and the phosphide is poured into an open cast-iron mould having a ridged bottom so that the metal can subsequently be broken up into small ingots approximately 2 sq. in. square by ¾ in. thick.

A NEW ANTI-CEMENTATION COATING

By L. M. KAMIONSKY. (From *Vestnik Mashinostroenia*, No. 2/3, 1946, pp. 71-72.)

IT is not always convenient or practicable to electroplate metal parts, and therefore to protect such parts pastes and paints which are often mixtures of copper and lead compounds bound with shellac or water-glass, etc. are used. For gear-boxes and other components a new combination has been found very effective in a Russian tank factory.

A mixture of 4 to 5 parts, by weight, of cuprous chloride and 2 parts of fine-ground red lead, in a binding liquid of 10 to 15 per cent of resin in ethyl or butyl-alcohol, benzine, or one of the nitro-solvents, is found to deposit a layer of copper on the metal whilst the cementation process results in the reduction of the lead oxide and the formation of a cupro-lead protective outer skin. The resinous varnish burns away and the final appearance of the coated surface is quite smooth requiring no further treatment.

In mixing this protective 'paint' the binding liquid is added until the desired painting properties are obtained.

Metal parts must be carefully degreased before being 'painted' with two or three coatings, after which they are ready within 20 to 30 minutes for packing into the cementation boxes.

RUSSIA

SELF-COKING ELECTRODES FOR ARC FURNACES

By L. I. Levy. (From *Vestnik Mashinostroenia*, No. 1, 1946, pp. 41-45, 2 illustrations.)

The standard electrode for electric steel furnaces is quite a heavy item in the cost of the metal and sometimes difficult to obtain quickly because it is made by highly specialized and powerful machinery with a considerable expenditure of electrical energy. During the war years, therefore, the "Dynamo" Works in the U.S.S.R. has been very successfully experimenting with electrodes made by themselves without any preliminary "baking" or "coking" process. They have now been used for about three years and have given every satisfaction in the manufacture of low-carbon and low-alloy steels in furnaces of 3 to 4 ton capacity, so that it is intended to extend their use.

The principal characteristics of the two main standard electrodes and of the Sonderberg self-coking type are as follows :

PROPERTIES	TYPE OF ELECTRODE		
	Graphited.	Compressed coal.	Self-coking.
Specific gravity (apparent)	1·57	1·55	1·52
Sp. resistance (per mm² area) ohms/metre	8 to 15	30 to 100	50 to 80
Permissible current density, amps/cm²	15-25	5-10	Less than 10
Temperature of oxidation, deg. C.	640/700	400-500	—
Ash content, per cent	Less than 1 per cent	Less than 5 per cent	Less than 8 per cent
Comparative cost per lb.	100	33	9

It will be seen from the above that the self-coking electrode is sufficiently similar to the compressed coal type to require no change in furnace dimensions.

ELECTRODE FILLING MIXTURE.

The basis of the mixture in its dry state is 30-35 per cent roasted anthracite or thermo-anthracite and 65-70 per cent of crushed metallurgical coke or electrode remnants. The dry mixture is heated for about 1-1½ hours with continuous stirring until a temperature of 110-120 deg. C. is attained. After this the binding materials are added, comprising coal tar pitch and coal tar (or anthracite oil in lieu of the latter), their total weight being 25-28 per cent of the weight of the dry mixture.

The mixing continues at the same temperature for another hour or more and can then be either used at once or put into stock.

THE ELECTRODE CASING.

The casing must be truly cylindrical, of sufficient stiffness, and provided with longitudinal internal ribs to grip the filling mixture. A suitable construction for electrodes of 8-16 ins. dia. is shown in Figs. 1 and 2.

It is built up of main sections (Fig. 1), of which there are usually three, and a conical end section (Fig. 2), which are welded solidly to each other making a total length of 8 ft. 6 in. They are made of sheet iron ·04 to ·05 in. thick.

To ensure a good joint between sections the ends are castellated, as shown, and the recesses form windows which permit of making sure that the internal ribs overlap correctly, while the protruding parts, slightly bent outwards, form a good guide for aligning the sections and later help to form a strong joint. When the sections have been aligned they are tack-welded together and then welded all along the joint. At the same time the lifting holes of the lower section are covered over and welded up.

The preparation of new castings, extension of partly used electrodes and the filling are all done over a 5 ft. deep trench covered over with a ⅜ in. thick steel plate in which holes have been cut to the diameter of the castings.

The filling mixture must be at 100-110 deg. C. and if that involves re-heating it is done in a bricked-in boiler and must not take longer than three hours, by which time

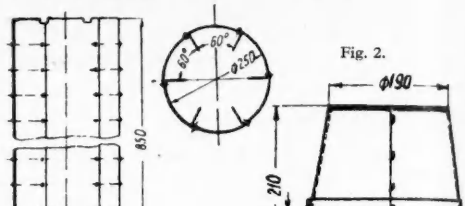


Fig. 1. Fig. 2.

it should have achieved the consistency of dough so as to fill the casting without leaving any voids. It is fed into the casings in small charges of about 30 lb. and patted into place with a wooden rammer. A casing is never filled higher than about a foot from the top so as to leave room for working when adding another section. When a new section is added the surface of the old filling must be cleaned to ensure good blending with the new.

INSTALLATION AND USE.

As the shape of the self-coking electrode is rather less accurate than that of the standard article and because allowance must be made for expansion, it is advisable to make the electrode opening in the economiser about an inch bigger than the nominal outer diameter of casing.

The terminal clamps must be water-cooled and so located that about one foot of *filled* casing should remain above it, i.e. 2 ft. altogether.

It is advisable to arrange for access to the electrode end by means of a suitable walk-way.

When a new electrode is inserted, the conical portion of its casing must be vented to facilitate the escape of gases by piercing 3/16 in. dia. holes in it at 3 in. intervals.

For starting, small coke and crushed remnants of electrodes are laid over the charge immediately below the electrode and the furnace switched on at minimum power and on hand-control.

A suitable starting règime is : 30 per cent of maximum power for the first hour, 50 per cent second hour, 85 per cent third, and after that full power and automatic control. This is the safe procedure and, with experience, the starting time can be cut down to 2-2½ hours.

If everything goes well, heavy black smoke should come from the electrode during the first 30 or 40 minutes, indicating strong coking action. During this period that part of the electrode which is inside the furnace will grow "fur edges" along the joints due to the filling being forced out and coking as it comes out. Before long it burns away and the electrode looks clean again. When black smoke disappears and only a little white smoke escapes through the economiser openings, the coking process is complete.

When an electrode has burnt low or has been broken it is withdrawn to the work-trench and extended by a further section (sometimes by two sections, but one is normal). Thus extended, it normally does not require a new period of "breaking in gently," but can go straight into service, with maximum power and automatic control. However, if an electrode has broken very short and has required two sections to build it up the furnace must be switched over to star connection (lower voltage) for 30 to 35 minutes, without reverting to hand control.

Three years of experience with this type of electrode have convinced the authors that they are a very sound proposition for low-carbon and low-alloy steels, and it is also suggested that they could be applied with great advantage to the manufacture of carbide and abrasives.

THE ROLL LINK AS THE BASIC ELEMENT OF PLANE GEAR DRIVES

A CONTRIBUTION TO THE SYSTEMATIC ANALYSIS OF TRANSMISSION-MECHANISMS.

By K. H. SIEKER. (From *Die Technik*, Vol. 2, No. 1, January, 1947, pp. 29-35, 51 illustrations.)

INTRODUCTION.

THE first practical classification system for transmission mechanisms was developed by F. Reuleaux[1], who after carefully analyzing many different types of gears, established six basic types of drives from which all other gear systems can be derived, viz.: screw types, crank, wheel, roller, curvilinear, and locking gear.

Further efforts with a view to reducing the six Reuleaux types to a single basic design have been made in more recent times by Rauh[2] and Franke[3] who used the four-link gear as the basic element, and by Von Voss[4] taking the lever-gear as a basis (see Fig. 4).

These new systems, however, have the disadvantage that complicated considerations are required to derive simple gear types ; for instance Franke regards a wheel rolling on a plane as a four-link gear in which the four links coincide at the point of contact of the wheel and the plane, and a guided roller is reduced to a seven-link gear ; while Rauh derives the roller of a curvilinear gear drive from a four-link design. These classification systems are complicated, because they are based on the four-link gear, whereas with a simpler basic element it should be possible to obtain the various combinations in a more natural manner. Most three-dimensional gears are such simple designs that they can easily be reduced to plane gears ; for instance the worm drive can be reduced to a wedge gear, and the bevel gear to the spur-wheel gearing.

THE ROLL-LINK ELEMENT.

A general theorem of kinematics states that any movement of a plane E_1 with respect to another plane E_0 which is in a state of rest can be represented by means of two curves rolling upon each other. For instance, if two points A and B of a plane E_1 (Fig. 1) move along curves a and b of a plane of reference E_0 there will be at any instant one point of plane E_1 which will remain at rest relatively to the plane E_0. This point P is known as the instantaneous pole of rotation, and it can be readily obtained as the intersection of the two normals to the guiding curves a and b at points A and B. When A and B move along curves a and b the pole P describes the curve p_0 in the plane E_0 and the curve p_1 in the moving plane E_1. Curves p_0 and p_1 are known as the herpolhode and the polhode, or the fixed pole path and the moving pole path of the motion, respectively. As these two curves are the loci of the instantaneous poles of rotation their points of contact at a given instant do not move relatively to each other, so that the pole paths roll upon each other.

Any type of motion in two dimensions can therefore be obtained by making two material curves k_0 and k_1 pertaining to the members G_0 and G_1 roll over each other, and G_0 and G_1 are thus guided in their relative motion (see Fig. 2). Following Franke's nomenclature, this arrangement will be called a " roll link " element. If slipping of the curves of contact is prevented for instance by using appropriate materials and avoiding excessively large force components in the direction of the curves' common tangent, and if the curves are maintained in constant contact by means of additional forces (such as gravity or spring force), it will be possible with roll link mechanisms of this kind to generate any type of motion required by appropriately designing the two rolling curves, with the restriction that the paths of the curves should not overlap. Under these conditions the member G_1 will be compelled to follow a certain motion with respect to G_0, which is assumed to be in a state of rest ; and with this guiding arrangement the three degrees of freedom of the motion of one plane relative to another, viz.: the two rectilinear motions in any two directions and one rotary motion about an axis perpendicular to the plane, will be reduced to one degree of freedom, i.e. a rotation about an axis perpendicular to the plane and intersecting this plane at the instantaneous pole, the point of contact of the two guiding curves. The position and motion of member G_1 and of all points on this member are determined relatively to member G_0 by the position of the instantaneous pole, which is determined by the shape of the guiding curves and the instantaneous angular velocity ω_{10} of member G_1 with respect to member G_0. The velocity of point A can be obtained, for instance when the gear is in the position indicated in Fig. 1, by taking from the pole's radius vector AP_{10} an angle ϑ_{10}, the magnitude of which is determined by the relation : $\tan \vartheta_{10} = m_\omega \cdot \omega_{10}$, the factor m_ω representing the scale of measurement of angular velocity. If the perpendicular to the pole's radius vector is constructed at point A, the distance along this perpendicular which is cut out by the branches of the angle ϑ_{10}, determines the length and the direction of the velocity vector at point A. If the length of this vector is $l_v = m_v \cdot v_A$, where m_v is the scale of measurement of velocity, and if the angle AP_{10} is denoted by r_A, then :

$$\tan \vartheta_{10} = \frac{l_v}{r_A}, \quad m_\omega \cdot \omega_{10} = \frac{m_v \cdot v_A}{r_A}$$

and furthermore $m_{10} = v_A/r_A$. Therefore the scales of measurement are equal, and their physical dimension is that of time : $m_\omega = m_v$ [sec.].

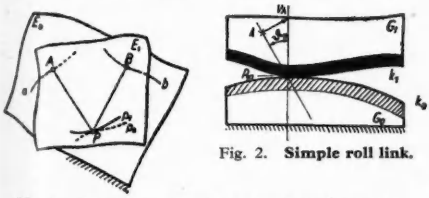


Fig. 1. **Instantaneous pole and pole path curves.**

Fig. 2. **Simple roll link.**

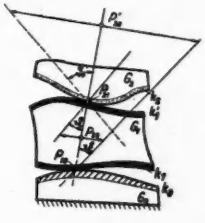


Fig. 3. **Double roll link.**

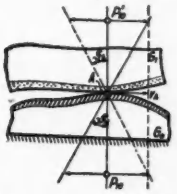


Fig. 4. **Single-point skid link.**

Even when the gear member which served as a frame of reference is no longer at rest, but also has its proper motion, the kinematic process can still be represented by the two pole path curves of the relative motion rolling upon each other. If in Fig. 3 the motion of member G_2 relative to G_1 is represented by the rolling of two curves k_1 and K_1 over each other, and if member G_1 performs a definite motion as a result of curve k_1 rolling on curve k_0, then these kinematic conditions can be determined by using these pole paths as guiding curves. The resulting mechanism will be known as a double-roll link. The motion of member G_2 has two degrees of freedom due to the fact that the velocity

ω_{10} of member G_1 relative to member G_0 about the instantaneous pole P_{10}, and the velocity ω_{21} of G_2 relative to G_1 about P_{21} can be arbitrarily chosen. The instantaneous pole P_{20} of the motion of G_2 relative to G_0 is situated on the connecting line $P_{10}P_{21}$ at the position at which the guiding velocity of G_1 relative to G_0 and the relative velocity of G_2 with respect to G_1 have equal and opposite values. By constructing the angles $\vartheta_{10} = \tan^{-1}(m_\omega \cdot \omega_{10})$ and $\vartheta_{21} = \tan^{-1}(m_\omega \cdot \omega_{21})$ with their corresponding vertices at P_{10} and P_{21} and the centre line $P_{10}P_{21}$ as one branch of these angles, the pole P_{20} can easily be found. Its position moves along the straight line $P_{10}P_{21}$ when ω_{10} or ω_{21} is changed. Thus the pole P_{20} will wander towards P'_{20} (Fig. 3), if while angular velocity ω_{10} is kept constant, the angular velocity ω_{21} is changed in magnitude and direction, until it assumes the value ω'_{21} corresponding to angle ϑ'_{21}.

If in the simple roll-link element not only the rotating motion but also a sliding of the curves relative to each other is permitted, then member G_1 will also perform a motion with two degrees of freedom. This link arrangement which is kinematically equivalent to the double-roll link will be termed a " skid-link." The member G_1 can rotate about point A relatively to member G_0 (Fig. 4) with an angular velocity $\omega_A = \frac{1}{m_\omega} \tan \vartheta_A$ and at the same time the entire member G_1 can have a rectilinear motion relative to G_0 with a velocity v_A. The direction of v_A is given by the common tangent to the two guiding curves at the point of contact A. Both variables ω_A and v_A are independent variables and can be arbitrarily chosen, so that the motion has two degrees of freedom. On the normal to the curves at point A there is a point P_{10} of member G_1, which is at rest at that instant, because the two velocities cancel each other out at this point. This point is the instantaneous pole of member G_1 ; its position on the corresponding normal depends on the magnitude and direction of ω_A and v_A. It moves, for instance (see Fig. 4) towards P_{10}, when ω_A changes in magnitude and direction and assumes the value $\omega'_A = \frac{1}{m_\omega} \tan \vartheta'_A$, while the magnitude of velocity v_A remains unchanged.

THE SKID LINK.

If the gear member has a second roll link contact with the fixed member G_0 (Fig. 5), then the motion of G_1 has only one degree of freedom, assuming of course that both guiding curves are constantly in contact. For instance, if the velocity v_A of member G_1 is given at point A, then point B, the point of contact of the second pair of rolling curves, will be compelled to move at a velocity v_B, which is already defined in magnitude and direction. The instantaneous pole P_{10} of member G_1 is situated both on the common normal of the first pair of skidding curves and on that of the second pair of curves, it is therefore determined by the intersection of these two normals. If the distances of points A and B to the instantaneous pole P_{10} are denoted by r_A and r_B then the velocity ω_{10}, with which the member G_1 rotates about the instantaneous pole P_{10}, is given by the relation:

$$\omega_{10} = \frac{v_A}{r_A} = \frac{v_B}{r_B} = \frac{1}{m_\omega} \tan \vartheta_{10}.$$

Velocity vectors v_A and v_B are therefore proportional to the distances r_A and r_B. This leads to the following construction : by drawing the velocity v_A with its given vector length in the direction of the pole's radius vector, i.e. perpendicularly to the correct direction, and drawing through the end of the vector a parallel to the connecting line AB, a vector of length v_0 will be cut off on the pole radius vector through point B. The motion of member G_1 can also be represented by the velocity v_A of point A and the angular velocity $\omega_A = \frac{1}{m_\omega} \tan \vartheta_A$ about point A, or by v_B and ω_B. The two velocities v_A and ω_A, contrary to the skid link of Fig. 4, are now no longer independent of each other, and the relationship between them is given by : $\omega_A = \frac{-v_A}{r_A}$ or $\omega_B = \frac{-v_B}{r_B}$.

The two-point skid-link just discussed is kinematically equivalent to the simple roll-link, whereas the one-point skid-link is equivalent to the double roll link. The single-point skid link can thus be called a two-valued link, while the two-point skid link and the simple roll link are one-valued systems.

THE SLIP LINK.

Particular types of two-point skid links can be obtained by rotating the curves of contact in such a way, that the instantaneous pole P_{10} will not change its position, so that the pole paths will degenerate into a point. Then either the curves of the moving member (Fig. 6) or of the fixed member (Fig. 7) will be concentric circles with their centres at the instantaneous pole. In this case the supporting curve will remain in constant contact with the circular arcs at the same points. This particular case of the two-point skid link will be called a slip link.

If the shapes in Figs. 6 and 7 are combined, the guiding arrangement will not have to be restricted to two positions, but can also be extended to the entire surfaces, with circular arcs of equal corresponding diameters rolling upon each other. Furthermore the two circular arcs can be united into a single arc (Fig. 8) giving a rotary link. If the instantaneous pole is situated at infinity the diameters will also be infinitely great and the circular arcs become straight lines, thus G_1 moves along the straight boundary line of G_0 giving the " slide-link " (Fig. 9). Slip links, including the rotary and the slide link types, are thus special cases of the two-point skid link and of the simple roll link.

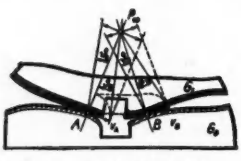


Fig. 5. **Two-point skid link.**

Fig. 6. **Slip link. Circular arcs as guide curves of moving member G_1.**

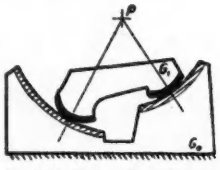


Fig. 7. **Slip link. Circular arcs as guide curves of stationary member G_0.**

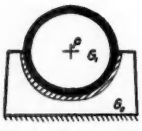


Fig. 8. **Rotary link.**

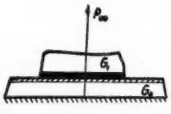


Fig. 9. **Slide link.**

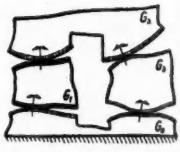


Fig. 10. **Four roll link mechanism.**

BASIC GEAR SHAPES.

Instead of using two single-point skid links (Fig. 4) combined into a two-point skid link (Fig. 5) for compulsory motion, two equivalent double roll links can be combined (Fig. 10); in this manner compulsory motion can also be obtained. The four-roll link gear thus created is the basic shape for all plane gear systems. A variant of this basic shape can be obtained by replacing one of the two double roll links by an equivalent simple skid-link (Fig. 11). The gear type thus obtained will be called a rolling skid link gearing. If in this gearing the intermediate member of the double roll link is taken as the frame of the gearing then another variant will be obtained (Fig. 12), which is the primary shape of a series of simple mechanisms. In Figs. 10-12 the curved arrows on the normals to the curves signify that the curves should only roll over each other, while the additional arrows on the common tangents of the curves signify that the curves can also slide against each other and perform a skidding motion.

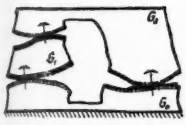


Fig. 11. **Roll skid link mechanism.**

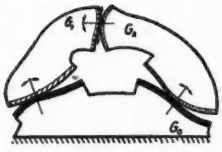


Fig. 12. **Roll skid link mechanism, kinematically the inversion of the system in Fig. 11.**

The simple mechanisms used in practice can be derived from the basic types by replacing general link and member shapes by special shapes. Thus for instance for simple roll links and slip links, the rolling and skidding curves can be replaced by circular arcs or straight lines. In this manner the Reuleaux types of basic mechanisms can also be derived from the four roll link and from the roll skid link system.

FOUR-SLIP-LINK MECHANISMS.

By replacing in the double roll link the two roll links by slipping links, either of the rotary or of the sliding type, the four various possibilities of double slip links illustrated in Figs. 13-16 can be obtained, viz. the double rotary link, the rotary slide link, the sliding rotary link, and the double slide link. By combining

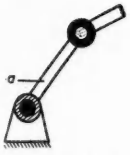


Fig. 13. **Double rotary link.** a = crank.

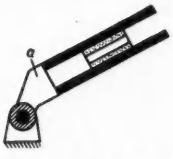


Fig. 14. **Rotary slide link.** a = loop.

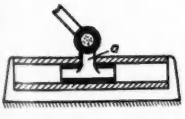


Fig. 15. **Slide rotary link.** a = slider.

Fig. 16. **Double slide link.** a = cross slider.

these double-link elements into four-link mechanisms, in principle, ten different types of mechanisms can be developed (see Figs. 17-26). There are no standard technical terms for the mechanisms of the four-slip-link

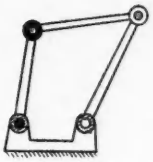


Fig. 17. **Double crank.** (Double swing, crank swing).

Fig. 18. **Crank loop.**

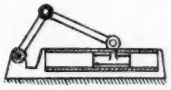


Fig. 19. **Slide crank.** (Slide swing).

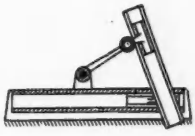


Fig. 20. **Cross loop crank.**

Fig. 21. **Double loop.**

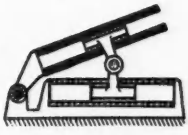


Fig. 22. **Slide loop.**

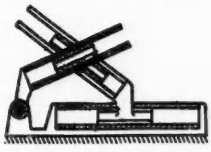


Fig. 23. **Loop cross loop.**

Fig. 24. **Double slider.**

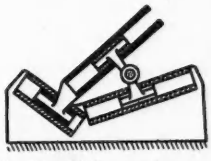


Fig. 25. **Slide cross loop.**

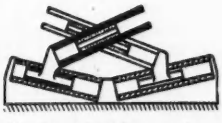


Fig. 26. **Double cross loop.**

chain in spite of their great importance. In accordance with the nomenclature of this article it is suggested that the following general lines should be followed in seeking an appropriate designation for a given mechanical system: The mechanism should be named after the members moving in the frame. Thus the member in Fig. 13 shall be called a crank, in Fig. 14 a loop, in Fig. 15 a slider, and in Fig. 16 a cross-slider. Furthermore in the case of the member in Fig. 13 a distinction can also be made between a crank arm and a swinging arm, according to whether the member in the drive can rotate or only swing. As a result, the following gear designations can be suggested: Fig. 17: double crank, double swing, crank swing; Fig. 18: crank loop; Fig. 19: slide crank, slide swing; Fig. 20: cross loop crank; Fig. 21: double loop; Fig. 22: slide loop; Fig. 23: loop cross loop; Fig. 24: double slider; Fig. 25: slide cross loop; Fig. 26: double cross loop.

In the loop cross loop and the slide cross loop of Figs. 23 and 25, the members connected by rotary links can no longer rotate with respect to each other; the rotating link is therefore superfluous and can only serve to

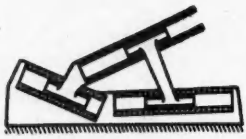


Fig. 27. **Wedge type mechanism.**

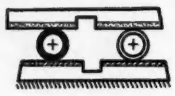


Fig. 28. **Roller straight line guide.**

compensate any inaccuracies or defects in the straight guiding lines. By omitting this link and connecting the two gear-members rigidly together, the wedge-type mechanism is obtained (see Fig. 27). This special type will be discussed in connection with other special mechanisms later on. The double cross loop in Fig. 26 is no longer a compulsory drive, as the two cross loops can move independently of each other.

ROLLER AND WHEEL.

A large group of other simple transmission mechanisms, used much more extensively in practice, is obtained by taking straight lines or circular arcs for the guiding curves in the four-roll-link gear arrangement. When roller shapes are used for the intermediate members of the double-roll links, and straight lines or circles for the opposite curves, the roller systems of Figs. 28 and 29 are obtained, which are employed in straight guiding systems or in bearings to decrease the frictional losses existing in slip-link gear.

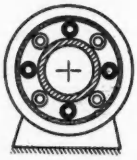


Fig. 29. **Roller bearing.**

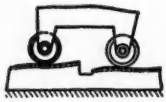


Fig. 30. **Wheel gear.** (Wagons).

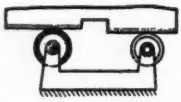


Fig. 31. **Wheel guide.**

Fig. 32. **Tension-type transmission.**

If in the double link systems one roll link is replaced by a rotary link in such a way, that the axis of rotation will coincide with the roll axis, then the wheel-gear series is obtained. Fig. 30 shows the wheel arrangement used in wagons and cars ; a variant is the wheel-guide system obtained by linking the wheels to the frame-element (Fig. 31). If in this case the drive member which transmits the rotary motion from one wheel to the other is only subjected to tension, then it can be replaced by a tension-transmission element such as a belt or rope, etc., which goes round both wheels as an endless band ; this gives the tension-type transmissions of Fig. 32. Another double-link combination with one wheel and one roller link is shown in Fig. 33.

CURVILINEAR GEARS.

Curvilinear gears with guiding rollers can easily be derived from the primary four-roll-link mechanism, by replacing three roll links by slip-links and using a wheel shape for the gear member which guides the roller, (Figs. 34, 35, and 36).

In the grip gear of Fig. 37 the driving member is a disk made of four circular arcs ; the yoke in the coupling member consisting of four straight surfaces with a square cross-section. According to the direction of the applied forces, two adjacent sides of the square will be participating in the transmission. The coupling member is also linked by means of a slot to a cylindrical pin of the

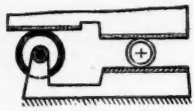


Fig. 33. **Combined wheel and roller guide.**

Fig. 34. **Curvilinear gear with guide roller, lower frame guiding.**

Fig. 35. **Curvilinear gear, driven member of rotary type.**

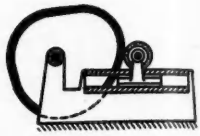


Fig. 36. **Curvilinear gear, straight line guided stroke member.**

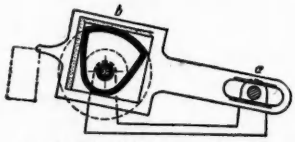


Fig. 37. **Curvilinear gear (eccentric), with two-point skid link.** a = single-point skid link.

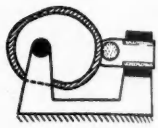


Fig. 38. **Curvilinear gear with skid link between curved disk and stroke member.**

Fig. 39. **Simplified crank loop. Skid link between crank and loop.**

Fig. 40. **Skidding curve gear.**

lower frame. Comparing this system with the modified primary drive of Fig. 11 which is a roll skid link gear, it will be seen that the roll link between the members G_0 and G_1 has become a rotary link and the roll link between members G_1 and G_2 has been replaced by a two-point skid link. The single-point skid link between members G_2 and G_0 is also present in the gear system of Fig. 37, but the two skidding curves have become a straight line and a circle. The proper contact is ensured both in the two-point and the single-point skid link by counter-flanks.

Modifications of the roll skid link gear of Fig. 12 can be obtained in the same manner, for instance by replacing the two roll links by slipping links. Fig. 38 shows for instance a curvilinear drive in which one of the roll links is replaced by a rotary link, while a slide link is used instead of the other. The curved disk transmits the motion via a cylindrical pin to the reciprocating member, thus one of the skidding surfaces is of circular shape.

In the mechanism of Fig. 39 the two roll links of the roll skid link gear are replaced by rotary links, and the skidding curves are a straight line and a circle, respectively. The motion is similar to that of the crank loop. (Fig. 18).

By substituting rotary links for the two roll links in conjunction with skidding curves of various shapes, the curvilinear drives and toothed gears of Figs. 40 and 41 are obtained. Toothed gearing is characterised by the constant transmission ratio of the two gear-wheels ; furthermore the curves of the teeth are set so close together that one pair of curves is already engaging

when the previous pair comes out of contact, and in order to ensure reversibility of motion the curves are on two sides thus giving the typical tooth contour.

LOCKING GEAR.

In the curves with a skid link (Figs. 37-40), the force is transmitted from one member to the other in the direction of the common normal of the curves or in a direction determined by the angle of friction relative to the normal. This force can only move the driven member if it is large enough to overcome the resistances

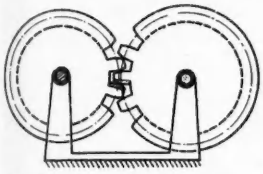


Fig. 41. **Toothed wheel gear.**

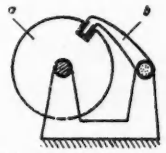


Fig. 42. **Bolt lock.**
a = locked piece,
b = locking element.

Fig. 43. **Cylindrical lock.**

Fig. 44. **Resting lock.**

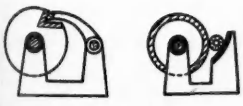


Fig. 45. **Directional lock.**

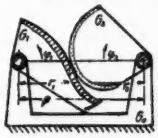


Fig. 46. **Directional lock with clutch effect.**

Fig. 47. **Rolling curve gear.**

due to frictional forces, spring forces, gravity, etc. If this force is perpendicular to the direction of guided motion, even the greatest force will not be able to give rise to motion. In such cases locking effects are obtained, which are used in gear systems (Figs. 42-46). In conjunction with other gear elements these locking devices will enable certain particular types of motion, e.g. switching, coupling, and other such types of motion, to be achieved. In the locking arrangements of Figs. 42 and 43 the locked piece is completely locked by the locking element, and it will only be able to move again when the locking element is released, i.e. moved out of the locking position. The locking cavity in the lock-piece can be shaped in such a way, that the locking element after overcoming a resistance is automatically forced out of the locking position ; this will be called a resting lock (Fig. 44). In the directional lock (Figs. 45 and 46) the locking element allows the lock piece to move only in one direction, and locks solidly in the other direction.

" IMPROPER " ONE-VALUED LINKS.

Generally speaking, the dimensions of transmission mechanisms can be varied without the transmission of motion being thereby affected. Only in extreme cases are locking effects the results of such changes. Some special cases are noteworthy because of their practical importance. In certain cases when very definite relative dimensions are used in mechanisms, which are evolved from the roll skid link gear, the two-valued skid will change into a single-valued roll or slip link system, or into a two-point slip link, which is one-valued as already stated. In this manner three-member gears with three single-valued links are obtained, whereas normally when only single-valued links are used four gear members are necessary to enable the individual members to move relatively to each other. A gear of this type, viz. the wedge mechanism, has already been derived from the four-slip-link chain (see Fig. 27).

If for the transmission of motion of two members connected to the frame by means of rotary links, the pole paths of the relative motion are used, then these curves must roll upon each other (Fig. 47). The gear system is somewhat similar to the skid-curve gear illustrated in Fig. 40, from which it can be thought of as having been derived by a substitution of a single-valued roll link for the two-valued skid-link. The point of contact of the guiding curves, i.e. the instantaneous pole of the relative motion, must always be situated on the centre line, the straight line connecting the two rotary link axes. This gives the conditions :

$$r_1 = \frac{p}{1+i} \text{ and } r_2 = \frac{p \,.\, i}{1+i}$$

where r_1 = distance of point of contact from axis of rotation of member G_1 ; r_2 = distance of point of contact from axis of member G_2 ; $p = r_1 + r_2$; $i = \mathrm{d}\varphi_1/d\varphi_2$; φ_1 = angle of rotation of member G_1 ; φ_2 = angle of rotation of member G_2.

If in this gearing the transmission ratio is to remain constant, then the relative pole must remain at a given position on the centre line, and the roll curves will become circles (Fig. 48). If these circular guiding surfaces have to transmit forces from one member to the other, this can only be achieved by friction. For this the surfaces must be pressed against each other by a normal force. Then either the elastic forces in the gear members themselves will have to be used, or the distance between the wheel axes can be made variable by introducing a further link, so that the complete gear system with four members and four one-valued links is again obtained.

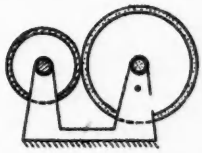


Fig. 48. **Frictional wheel gear.**

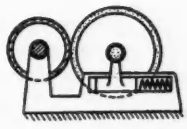


Fig. 49. **Complete friction wheel gear.**

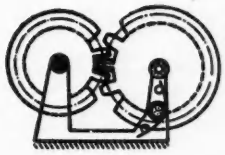


Fig. 50. **Toothed wheel gear with two-point skid link at the teeth.**

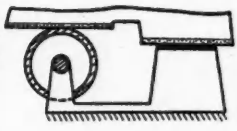


Fig. 51. **" Improper " slip link wheel gear.**

The toothed-wheel gearing with tooth clearance (Fig. 41) is, as already stated, a special type of skid-lever gearing. The single-point skid link between the wheels becomes a two-point link, if the gearing is without tooth clearance. Thus the three member gear has only three single-valued links. The actual guiding of the tooth at two points will however only be maintained over the entire course of the gear's motion if the tooth profiles are made with great accuracy. Any deviations from the

required shape can be detected and compensated with a two-flank testing set, by varying the distance between the axes, i.e. by using a further link through which the tooth flanks will press against each other (Fig. 50). The gearing will thus be complete again, with four members and four one-valued links.

Fig. 51 shows a further three member gear, which owing to the particular dimensions used has only three one-valued links. It can also be imagined as derived from the mechanism of Fig. 33 by omitting the roller and letting the members slip directly upon each other.

In all these gear types with particular dimensions, one of the three one-valued links must be regarded as an improper link, the choice depending on the manner in which the special gear is assumed to have been derived from a complete mechanism.

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FRANCE

LOW OIL CONTENT CIRCUIT BREAKERS FOR MEDIUM VOLTAGES

By C. BRESSON. (From *Bulletin de la Société Française des Électriciens*, Vol. 6, No. 60, June/July, 1946, pp. 259-265, 11 illustrations.)

I. INTRODUCTION.

DURING the last 30 years the oil circuit breaker has been the only type used for the interruption of important circuits of medium voltages.

Accidents due to inflammability of the oil and explosive properties of the gases liberated by the arc have led to more rational studies of the interruption phenomena and the development of several types of air circuit breakers. In view of this it may be asked: is the oil circuit breaker still of interest ?

Two facts ought to be considered.

(a) A great number of such breakers is in service and their number is growing continuously.

(b) The modern oil circuit breaker is a low oil content breaker which is based on an entirely new technique which is largely the result of investigations carried out in test stations.

This article deals with the essential characteristics of this type of breaker and compares it with air breakers.

II. CHARACTERISTIC PROPERTIES OF LOW OIL CONTENT BREAKERS.

(a) INTERRUPTION IN OIL. Fig. 1 represents an arc started by the separation of two contacts under oil. The arc can be considered as a conductor of constant current density, i.e. of a diameter d proportional to $\sqrt{i}$, because its voltage drop, though proportional to its length, is independent of its current.

This diameter does not vanish when the current passes through zero because of the calorific hysteresis ; it retains a certain value d_0 which is the larger the larger d had been before, and the more quickly the current decreased (Fig. 2). This means, it depends upon the peak current I. This residual conductor must be made an insulator as quickly as possible to prevent restriking.

Three cases must be distinguished according to the importance of I.

(1) The interrupted current is weak. (Tens of amps.) ; d_0 is small. At current 0 no energy is released by the arc. Hydrogen, having a great heat conductivity, cools quickly ; at 2000 deg. C. (3632 deg. F.) it is no longer a conductor. The reduced pressure in the gas bubble assists vaporisation from the inner oil wall and produces vapour and liquid droplets which are thrown towards the core of diameter d_0, thus building up the dielectric strength.

(2) The interrupted currents are of medium strength, (hundreds of amps.) ; d_0 is now larger. The cooling of the gaseous conductor is more difficult because the ratio of the surface to the volume of the core decreases and the distance of the evaporating surface increases due to the larger gas bubble size.

The regeneration of the dielectric strength is less efficient and a greater length of the arc core is required to resist the recovery voltage. Similarly, a larger distance D is needed for interruption (See Fig. 3).

The cooling action of the bubble surface can be put into evidence because it is manifest during the existence of the arc. If a current is interrupted in a cylindrical vessel, the following experimental results are obtained (provided the head of oil above the arc is sufficiently great to prevent too quick displacement of the oil under the effect of the arc gases, Fig. 4) ; the arc voltage increases in proportion to the distance between the contacts ; taking into account this arc gradient g, it varies with the interrupted current as shown in Fig. 5. The arc tends to become stable, being no longer influenced

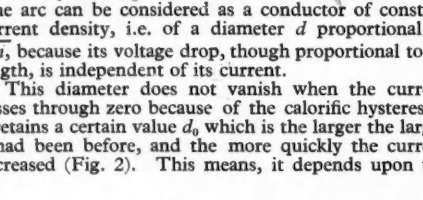

Fig. 1.

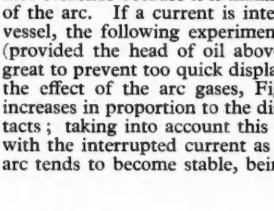

Fig. 2

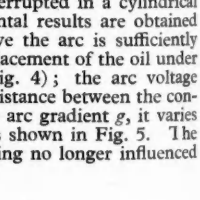

Fig. 3

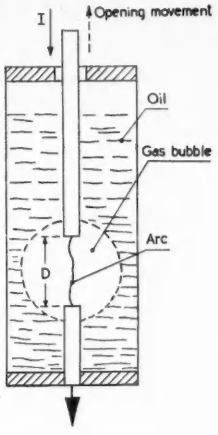

Fig. 4

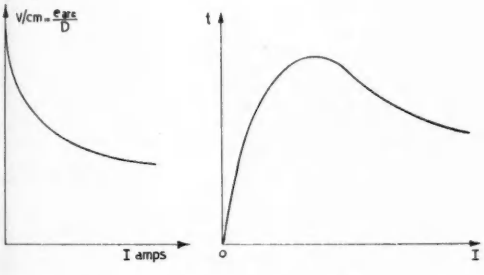

Fig. 5 Fig. 6

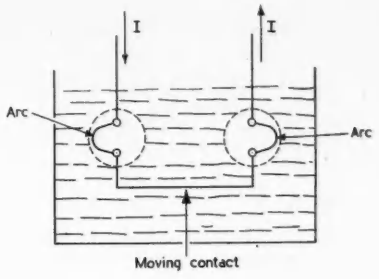

Fig. 7

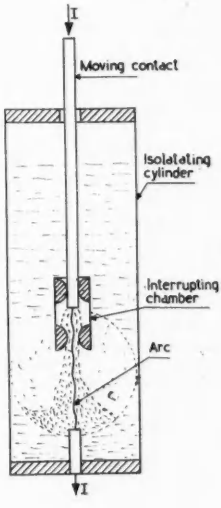

Fig. 8

by the cooling effects of the now remote bubble surface.

It is also found that the interrupting gap width does not vary with the speed v of the contacts for a given current ; the breaking time t, however, varies, of course, as $1/v$. Furthermore, the total breaking distance grows with the number of breaks in series, e.g. for 15 amps.:

$D = 7$ cm. (2·8 ins.), $g = 120$ V/cm. (305 V/in.) for one break, and

$D = 6 \times 3 = 18$ cm. (7·0 ins.), $g = 45$ V/cm. (114 V/in.) for six breaks.

This increase in D is due partly to a bad voltage distribution between the six breaks and partly to the fact that the cooling action is less efficient with six breaks, because there are six arc roots instead of two ; these roots are the portions of the arc where most of the gases are produced and which are most difficult to cool.

It is, therefore, not surprising that the low oil content breakers use one break only.

(3) The current is high (thousands of amps.) ; the interrupting distance increases further with the current as can be shown with the experimental arrangement described above.

Fig. 6 shows, for a given contact separation speed, the rupturing time of a classical two-break oil circuit breaker as a function of the current I. The voltage gradient of the arc grows. The apparently reduced arc length above a certain current is due to secondary phenomena facilitating cooling by vaporisation or by bringing the arc core and the evaporating surface closer together.

There are, furthermore :

The electro-dynamic forces due to the loop formed by the circuit in one phase (Fig. 7) ;

The electro-dynamic forces between neighbouring phases ;

The holding-back action of the gas bubble which tends to lower the pressure (oil piston). This action must be sudden, and consequently the movement of the piston will be rapid, without, however, appreciably increasing the volume of the bubble. (This would mean the risk of too large a distance between the arc core and the bubble surface). This explains the desirability of a small mass of oil and a volume of air, enclosed almost hermetically between the surfaces of the oil and the top plate. This result is contrary to what was previously thought to hold good.

(b) Realisation of Low Oil Content Circuit Breakers. A large volume of oil being no longer necessary, the interrupting device is not put in a tank but in an insulating vessel of cylindrical shape, mounted on supporting insulators. For the interruption a minimum quantity of oil is used, the arc is kept straight and immovable, and the gas bubble is regarded as generating gases and vapours for its extinction, experiences with the air blast breakers being turned to account.

The arc is drawn out quickly by the moving contact to the length required for extinction, (depending on the

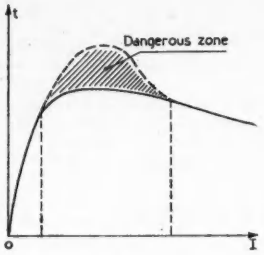

Fig. 9

voltage), and a bubble is formed (Fig. 8). The arc then enters a chamber and there produces gases under high pressure while the vaporising surface is kept close to the arc core. The enclosed vapours and high pressure gases produce an axial blast in the bubble.

It may happen with high voltages and small currents that the generation of gases is insufficient, in this case it is necessary to inject oil by an auxiliary mechanical device. The dangerous zone of long interrupting times is thus eliminated and the breaker shows a practically constant interrupting time for the whole range of currents (Fig. 9).

(c) COMPARISON OF LOW OIL CONTENT BREAKERS WITH AIR BLAST BREAKERS. The important properties of the low oil content breaker are :

(1) *The energy required for the interruption is provided by the breaker itself.*

(2) *The energy thus produced is proportional to the current to be interrupted* (for a given voltage). The air breaker always produces the energy required to interrupt the maximum current which is not necessarily the best condition for the interruption of small currents.

(3) The interrupting energy of the low oil content breaker is produced by the arc and is in its vicinity. For high currents the efficiency of the blast and the recovery of the dielectric strength of the arc gap are so great that *the breaker is only slightly sensitive to the natural frequency of the circuit* ; it is, however, sensitive to the value of the maximum voltage, as the dielectric has not very great strength. In the air breaker, the maximum rate of rise of the restriking voltage which the breaker can interrupt is fixed by the pressure and the velocity of the air and decreases if the interrupted current decreases. The ability of the breaker to interrupt the circuit depends very much on the rate of rise of the recovery voltage ; it is less sensitive to the tension, because the dielectric strength of the compressed air in the contact gap is high.

Resistance switching as applied to air blast breakers is only rarely used with low oil content breakers unless small currents have to be interrupted.

(4) *The low oil content breaker functions without noise.*

(5) The production of inflammable gases still represents a danger, but experience shows that this *danger is not comparable with that of the old oil circuit breaker.* This has been shown for breakers of medium interrupting capacity (200 MVA) fitted with a valve which opens under the pressure developed by the interruption. The oil is thrown out in droplets, the arc gases expand violently and no fire ensues. Experience shows that fires are only started if a sufficient volume of oil is heated and if the temperature is high enough. These conditions are satisfied by the old type of breakers, the produced gases burning on the surface of the oil.

(6) As the oil is not renewed immediately after interruption the following consequences have to be taken into consideration :

The arc gases remain in the oil for some time, forming an emulsion or being even partly dissolved. *Quick automatic reclosure can therefore only be obtained by introducing special devices for renewing the oil after each interruption.*

The carbonization of the oil (of the order of 30 mg. of carbon per kilowattsec. of arc energy) is getting more important as the number of interruptions and the currents increase. If the carbonization is not excessive, it will not weaken the interrupting capacity of the breaker ; the oil retains its dielectric properties provided the electrical clearances are sufficient and the oil contains no moisture (Fig. 10).

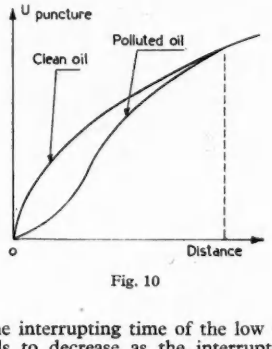

Fig. 10

(7) As the interrupting time of the low oil content breaker tends to decrease as the interrupted current increases, *there is no limit to this breaker's capacity.* In practice, however, such a limit exists and depends on the mechanical robustness of the mechanism which is subjected to the electro-dynamic forces. The interrupting capacity of the air breaker is better defined as it is limited by the known auxiliary pneumatic energy.

(8) Arcs occur not only on breaking, but also on *making a circuit.* This is more difficult, for large currents, with an oil circuit breaker than with an air breaker because of the sudden pressures set up in the gas bubble.

III. CONSEQUENCES OF THE CHARACTERISTIC PROPERTIES.

(a) The examination of the characteristic properties of the low oil content breaker shows that the problem of interrupting large short circuit currents of low tension has not yet been solved satisfactorily (Say 20,000 amps. and 15 kV). We cannot yet control completely the arcing time but only the arc voltage. There will be, therefore, some uncertainty with respect to the energy and its effects, especially the electro-dynamic forces. There is still the danger of a large volume of explosive gases and the nuisance of strong oil carbonisation. The low oil content breaker therefore does not offer the same safety as the air breaker does for large short circuit interrupting capacities of medium voltage.

(b) For medium and small short circuit interrupting capacities no mechanical problems are introduced by the arc energy, or by the gases and deposits developed in proportion to the available oil volume which is kept as low as possible.

An ordinary oil circuit breaker for 15 kV and an oil volume of 100 litres (22 gallons) interrupts 6000 amps. in ·06 secs. releasing 180 kW secs. per pole, i.e. 5·4 kW secs./litre (24·5 kW sec./gallon) ; a low oil content breaker with 8 litres (1·75 gallons) per pole interrupts in ·02 secs. and releases 4·8 kW secs./litre (21·8 kW secs./gallon).

The air breaker is the appropriate breaker for small interrupting powers ($\leq$30 MVA) and very large interrupting powers ($\geq$ 500 MVA). It shares the medium range with the low oil content breaker.

RECENT PROGRESS IN THE USES OF GLASS AS A STRUCTURAL MATERIAL

By B. LONG. (From *Bulletin Technique du Bureau Veritas*, Vol. 28, No. 6, November-December, 1946, pp. 127-133, 8 illustrations.)

THIS article deals with both the basic scientific work and with its practical application, in the form of new uses of certain types of glass.

SCIENTIFIC OBSERVATIONS ON THE MECHANICAL PROPERTIES OF GLASS.

The characteristic properties of glass are its transparency, its resistance to the corrosive action of the atmosphere, and its brittleness.

This brittleness can be explained by the fact that glass does not, at ordinary temperatures, undergo any plastic deformation when stressed. Hooke's law of proportionality between load (stress) and deformation (strain) is valid up to the point of rupture, and there is no "elastic limit."

The belief in the plasticity of glass at ordinary temperatures is based on the notion that glass is a liquid of exceedingly high viscosity. By extrapolation the viscosity of ordinary glass at 20 deg. C. (64 deg. F.) has been found to be of the order of 10^{76} poises. A calculation shows the absurdity of the belief in the slow flow of glass at ordinary temperatures. Further proof of the rigidity and permanence of shape of glass is provided by the fact that large astronomical mirrors consist of a base of glass supporting an extremely thin layer of silver or aluminium. Glass is in this case superior to many other materials, e.g. steel.

It is considered that the characteristic property of a solid is its return from deformation to its original shape after it has been relieved of external loads. According to this criterion silica glass is the most typical solid known.

Several physicists have studied the relationship of the rigidity of glass and its brittleness. It appears that the surface of the glass is covered by microscopic cracks whose number and direction vary according to the conditions of solidification during hot shaping of the glass. When such a piece of glass is loaded, stress concentrations occur at the bottom of the cracks, and as no plastic flow relieves these high stresses, failure in tension occurs at comparatively low average stresses. It is possible to increase the strength of glass by treating the surface with diluted hydrofluoric acid, which is considered either to remove the thin layer containing the cracks or to round off their profile.

This treatment increases the tensile or bending strength of glass specimens by as much as ten times, provided that care is taken not to touch the surfaces of the glass after treatment.

Another method of strengthening glass is the neutralisation of the surface cracks by precompression of the surface layers and corresponding tensioning of the core. In this case fracture does not occur until the tensile stress due to external loads exceeds the precompressive stress. The surface cracks are closed by the precompressive stress, and failure of the glass occurs only when this closing stress is overcome sufficiently by external stresses to open the cracks.

The formation of minute surface cracks also explains the effect which water has on the strength of glass. Humidity penetrating to the bottom of the cracks becomes adsorbed and seems to break down the bond between the silica molecules and the basic constituents of the surface layer. The elimination of the surface layer reduces the adsorption to one-third. A change in the degree of humidity surrounding the glass may change its strength by several per cent, and complete drying out in a vacuum may increase its strength to twice or three times the original value.

Fatigue of glass is another phenomenon which greatly affects its strength. It is shown, in a table comparing stresses at failure caused by loads applied for varying periods, that passing from a load duration of 10^{-2} seconds to one of 10 seconds, the ultimate stress is almost halved, and passing on to 10^{5} seconds it becomes less than one-third of the ultimate stress with a load duration of 10^{-2} seconds.

Fatigue of a specimen measured as expressed by the ratio of ultimate stresses at two load durations, one short and the other long, is found to be small at low temperatures, grows suddenly very large around the freezing point of water, remains almost constant for the next 200 deg. C. and then falls to a small amount between 400 deg. and 500 deg. C. The author interprets these changes by the surface adsorption of water. At low temperatures the layer affected by humidity is comparatively deep, but the humidity itself is inactive. At high temperatures the humidity is active, but penetrates to an extremely shallow depth. In the temperature zone between these extremes, penetration is comparatively deep and the humidity active.

It is not possible as yet to manufacture great thicknesses of glass of complete homogeneity. If, therefore, an attempt is made to neutralise the weakening effect of the skin by increasing the thickness of glass, flaws and discontinuities are observed in the mass which will lead to stress concentrations and so be sources of weakness. After dealing with the problem of the skin by toughening the glass, i.e. by putting the skin in precompression, the glass makers are now concentrating on the question of improving the homogeneity of thick masses. The author considers the progress so far made, particularly in the United States, so encouraging that he predicts a solution in the near future.

When an accurate calculation of the strength of glass—as of other materials of construction—is attempted, great difficulties are encountered because the physical constants of glass are by no means definite. Young's Modulus of Elasticity of glass is usually taken to amount to about 7,000 kg. per sq. mm. (about 10×10^{6} lb. per sq. in.) in the case of common soda-lime glass at ordinary temperatures, but no value, even approximate, of the tensile strength of any particular glass can be indicated with certainty. The ultimate tensile stress varies, for instance, with the diameter of the piece under test, increasing greatly with decreasing thickness until values of several hundred kg. per sq. mm. (several hundred thousand lb. per sq. in.) are reached with a diameter of ·001 mm. (·00004 in.). This compares with a few thousand lb. per sq. in. with specimens a few mm. (say ·1 in.) thick. Sheets of a thickness of several mm. (·1 in. or more) have an ultimate strength of about 4,250 lb. per sq. in. if their surfaces are mechanically polished. If the surfaces are fashioned by hot tools the strength will be about half the above value. A considerable factor of safety is indicated in practical calculations.*

Factors other than the diameter, influence the strength of glass, e.g. heat treatment, but to a lesser extent. The author suggests that in every case the reduction of surface cracking, both in size and in frequency, leads to an increase in strength.

*In Great Britain commercial fibres are now drawn with diameters of ·0002 in. which are said to have a tensile strength of 500,000 lb. per sq. in.

An approximate average of the ultimate bending stress in 26 oz. sheets (as determined by the Department of Glass Technology, Sheffield, and the Building Research Station) amounts to between 6,000 and 14,500 lb. per sq. in., according to the treatment of the edges of the specimen.

Contrary to the view expressed in this article, the Department of Glass Technology appear to attribute the lower stresses to polished glass ("plate glass") on the assumption that the grains of the polishing medium cause minute surface cracks.—Editor, ENGINEERS' DIGEST.

NEW MATERIALS OF CONSTRUCTION.

They fall into two categories aiming
(a) at mechanical strength, and
(b) at increased comfort or better appearance.

The first category consists of glass reinforced with welded steel mesh, corrugated reinforced glass, and toughened lightweight blocks for translucent concrete. The second contains double panes, hollow bricks assembled at great heat, multicellular glass, and the various glass fibre products.

(a) (1) *Glass reinforced with square welded mesh.*

This is primarily a safety glass, mostly used for roofs. Even after fracture the reinforcement holds the pieces of glass together so avoiding injuries. A further advantage is that, though cracked by heat, reinforced glass remains in place and so avoids access of further air to fan a fire which may have broken out in a building. The disadvantages of this type of glass consist of its unsightliness and its tendency to crack. The latter has been attributed to the difference in the coefficients of thermal expansion of glass and steel (the coefficient of glass at ordinary temperatures is 30 per cent less than that of mild steel), but the author rejects this view because at the temperature of fabrication of reinforced glass the coefficients are similar.

The question is asked whether toughened glass is not preferable to the reinforced type for use as safety glass. Toughened glass has great mechanical strength, and when fractured its splinters are small and have blunt edges. On the other hand heat-treated glass shows greater surface cracking. There is also to be considered that it is difficult to obtain homogeneous glass, and that it is necessary to use glass of a thickness of 5 to 6 mm. (·2 to ·25 in.) in order to obtain satisfactory toughening.

In recent years reinforced glass has been improved in two ways. The reinforcement has been prevented from oxidisation by surface treatment or alloying and by improved methods of welding the mesh, so giving better bond with the glass; and the rate of cooling of the glass has been adjusted to reduce brittleness in the glass.

(a) (2) *Corrugated reinforced glass.*

This type was developed in order to obtain greater strength and, as it is used chiefly in roofs, to facilitate matching with corrugated asbestos-cement sheets. Its manufacture on an industrial scale has only become possible by the development of continuous cooling of the glass and of a hexagonal mesh reinforcement in a mild steel which does not require a chromium coating for its protection. The most usual pitch in France is 73 mm. (about 3 in.) with a depth of corrugation of 25 mm. (1 in.). Three types of standard sheets are now commercially available.

(a) (3) *Toughened lightweight blocks for translucent concrete.*

Translucent concrete or glass concrete is the name given to a combination of reinforced concrete and glass blocks. Failure due to shrinkage of the concrete can nowadays be avoided, and so can the effect known as spalling under heavy load.

In the early days a proprietary make of block (" Securex ") whilst causing a reduction of weight of the structure, still suffered from the necessity of using a high factor of safety in design. This has proved justified only where shock or heavy moving loads have to be withstood. At the same time the squat shape of this type of block led to much absorption of light. A new type (" Securex-Lumax ") was, therefore, developed for structures not subject to moving loads, e.g. cupolas, which combines with toughness and a high resistance to static loading the advantages of minimum weight and maximum transmission of light. A further point in its favour is that, due to a ridge near the front face and a certain narrowing down towards the back, each block can, in case of accidental damage, be easily replaced.

(b) (1) *Double panes, and hollow bricks assembled hot.*

The demand for more light in buildings and an increase in the size of windows has led to a corresponding increase in the thermal losses. The remedy of double windows as applied in colder climates has the disadvantage, amongst others, of condensation on the outer pane. In order to solve this problem certain experiments were made which led to the conclusion that the thermal conductivity of a pair of parallel panes of glass with an airtight seal round the edges is almost independent of the thicknesses of the panes and little influenced by the distance between them. The use of two thin panes fixed on a sealing frame and with a gap of 3 to 6 mm. (1/8th to 1/4 in.) has, therefore, been considered, and has reduced heat losses to about two-thirds of those of a single glass sheet.*

A practical application of this principle consists of the use of two panes slid into a rubber or plastic frame. Even though this frame may provide a perfect seal, the air in the space between the panes may contain humidity which condenses on cold days. A method used in the United States to overcome this disadvantage consists of desiccating the air entrapped between the two glass panes and the plastic frame. If in addition the glass of the frame is normalised, this method should produce excellent results.

Hollow glass bricks, like double-walled partitions and double-pane windows, were originally introduced to improve thermal insulation. Today, however, they are chiefly used in cases where heat loss matters little, but where non load-bearing translucent walls are required, such as in the subdivision of large rooms into smaller ones. One make (" Verisolith ") has been used in France for several years. The Verisolith unit consists of two toughened half-bricks joined together by means of metallic solder. This unit can carry considerable loads.

Another type, such as the " Primalith " brick, is designed to be used as walling in framed buildings or in internal partitions. As these bricks are to be little stressed they are not toughened. The hollow halves, with the joining edges softened by small auxiliary heaters, are pressed together after moulding. This means that the enclosed air is hot and dry, and condensation at low temperatures is avoided. The four sizes of " Primalith " bricks, all 80 mm. (about 3 in.) wide, are 300 × 300, 245 × 120, 200 × 200, and 120 × 120 mm. (i.e. 12 in. × 12 in., 10 in. × 5 in., 8 in. × 8 in. and 5 in. × 5 in. approximately), each with a corresponding corner brick. Heat loss through a partition constructed of these bricks is roughly the same as that of a double window, viz. 4·5 kg. cal. per sq. metre per deg. C. per hour.

(b) (2) *Multicellular glass.*

This material is very light, its density being ·15 (about 9·5 lb. per cu. ft.) and has good heat-insulating properties, but it is unfortunately opaque. It consists of small cells completely separated by glass partitions, and because of its structure is sometimes referred to as foam glass. The process of manufacture consists essentially of heating glass powder and finely divided carbon, well mixed and placed in a steel mould, to 900 deg. C. The slabs of foam glass are used for heat-insulating purposes in outer walls, floors, roofs, etc. The heat loss through multicellular glass 80 mm. thick (about 3 in., for comparison with the above bricks) is about ·5 kg. cal. per sq. metre per deg. C. per hour. This material, though dearer than other types of insulating board, is moisture-proof, fire-resistant, vermin-proof, and very durable.

(b) (3) *Fibre glass.*

Manufactured in diameters of 2 to 12 thousandths of a mm. (·00008 in. to ·0005 in.) glass fibres are utilised according to their length, and also to their method of production. Long fibres are used chiefly for textiles, short fibres for thermal insulation. Mixed they are

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used for the production of sound-absorbing materials.

A thicker fibre (·001 in. diameter) has been made into a felt about ·1 in. thick which is placed between sheets of glass so producing a translucent, heat-insulating material called " Thermolux " which has great power of light diffusion.

Glass fibre for thermal insulation is usually obtained in the form of felts or mats.

Commercial felts, in France, consist either of a thickness of 1·5 in. bonded to resinous paper and with an apparent density of ·04 (2·5 lb. per cu. ft.), or of a thickness of about 1 in. sewn between two layers of paper and possessing an apparent density of ·06 (3·75 lb. per cu. ft.). Thermal insulation of roofs (much neglected in the past) as well as of walls is simplified by the use of these felts, fixed in different ways.

An example of the thermal insulating properties of this felt is quoted. Taking a 380 mm. solid brick wall as transmitting 100 heat units under certain conditions, it was found that a cavity wall consisting of an outer leaf, 120 mm. thick, of solid glass bricks, a 60 mm. cavity, and an inner leaf, 120 mm. thick, of hollow bricks, with plaster on both sides of the wall, transmitted 97 units. Inserting a 1 in. felt into the cavity, the loss was reduced to 50 units; and a 2 in. thickness of felt reduced it to 34 units, all under the same conditions.

Finally mention is made of the sound-absorbing properties of fibre-glass felt.

RUSSIA

FLUE GAS HEATED STEAM DRYER

By L. MAISEL. (From *Zheleznodorozhni Transport*, No. 8-9, 1946, pp. 73-75, 2 illustrations.)

COMPLETE utilisation of the expanded steam of a locomotive is known to be difficult, as it depends upon the interaction between boiler and engine. One kg. of exhaust steam is capable of raising the temperature of 7-8 kg. of feed water to 90 deg. C., but by this method no more than approximately 15 per cent of the available exhaust steam can be utilised. In doing this the operation of the blast pipe will not be affected. At high rates of evaporation the flue gases leave the boiler at an average temperature of up to 390 deg. C. Some of this heat could be utilised for preheating the combustion air. As regards the saturated steam delivered by the boiler, its temperature cannot be increased by heating until all its moisture is evaporated. Considering that the temperature of the saturated steam delivered by Russian locomotive boilers is 197 deg. C., a temperature difference of 190 deg. C. between the temperature of the rejected flue gases and the saturated steam exists. If the steam is supplied to the superheater with a moisture content of 5 per cent, then up to 25 per cent of the entire superheater surface will be utilised for evaporating this moisture.

The drying process will be completed in the superheater elements at the point where the steam flow changes its direction by passing through a return bend. Consequently, at this point one must expect the maximum deposition of incrustation to take place. This is confirmed in practice by the experience that failure of a superheater element usually occurs at this return bend. These circumstances, in conjunction with the fact that the heat transfer from the flue gas to the saturated steam is larger than that from the flue gas to air, gives rise to the proposal of a flue gas heated steam dryer. In this type of steam dryer the gases leaving the boiler are utilised for drying the steam prior to its admission into the regular superheater. With a scheme of this kind the temperature of the steam will be increased by 50-60 deg. C., while the gas exit temperature will be correspondingly lowered owing to the abstraction of heat from the gases for the drying of the steam. The heating surface of a steam dryer of this type approximates to 40-50 sq. m.

The modernisation of a locomotive by the installation of a steam dryer is exceptionally advantageous insofar as every 10 deg. C. increase in superheat will yield not 1 per cent increase in fuel economy, as is the case in usual practice; but will actually yield 2 per cent. Also, the installation of a steam dryer offers the advantage that is does not require any radical alterations of the boiler to be carried out; nor does it require any alterations of the superheater.

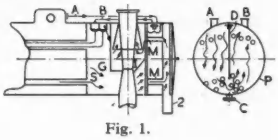


Fig. 1.

By combining the preheating of feedwater with flue gas steam drying two important tasks are performed, namely (a) that of lengthening the service life of the boiler and of the superheater elements, and (b) that of considerably increasing locomotive economy. The installation of a flue gas type steam dryer is shown in Fig. 1. Here the dryer is seen to consist of the drum P and two tube plates which are connected by a number of short tubes M arranged in appropriate manner. At the top of the drum two steam connections A and B are provided, while a drain valve C is attached to the lowest point of the drum. The dryer is placed in front of the smoke box of the boiler, and it is suspended by means of individual slings in order to provide access to the smoke box in the usual manner. In the front part of the dryer an ash clean-out door is provided at the hopper Z.

The smoke box is divided into two compartments S and I between which the baffle G is arranged. Saturated steam from the steam dome O is passed into the steam dryer through the pipe A and then flows around the internal baffle D of the steam dryer. The dry steam is discharged from the dryer into the pipe B through which it is passed into the saturated superheater header, and so forth. The flue gases pass around the baffling in the smoke box and enter the lower flue tubes M of the steam dryer. They subsequently change their direction of flow and pass through the upper tubes M, from whence they are discharged into the chamber I. From the latter they are finally ejected to atmosphere by the action of the blast pipe.

For the purpose of daily removal of flue dust from the chamber I the sides of the smoke box are provided with airtight clean-out doors. In order to maintain the draught in the furnace at its original level, the nozzle area of the blast pipe theoretically should be diminished from 0·0154 sq. m. to 0·01479 sq. m., which corresponds to a decrease in nozzle diameter from 140 mm. to 137 mm. But this measure did not actually prove necessary. The weight of the steam dryer amounts to approximately 2 tons.

From the thermal point of view the installation of the steam dryer has proved a great success. The installation of the relatively small dryer surface of 50 sq. m.—equivalent to 25 per cent of the heating surface of the boiler proper—secures an increase in superheat by 60 deg. C., resulting in a fuel economy of 14 per cent. The magnitude of this saving is explained by the fact that the increase in the heat content of the steam derived in the dryer from the flue gas is obtained not at the expense of the evaporative capacity of the boiler as would be the case if drying were accomplished by merely increasing the superheater surface. In addition to the fuel saving achieved, which for everyday conditions may be estimated as 10 per cent, the dryer also protects the elements of the superheater against encrustation and consequently ultimate destruction of the return bends by overheating.

SWITZERLAND

UTILISATION OF SUPERSONICS FOR THE TESTING OF MATERIALS

By H. BÖMMEL and R. V. BAUD. (From *Zeitschrift für Schweisstechnik*, Vol. 36, Nos. 9 and 10, September and October, 1946, pp. 185-187 and 207-209, 8 illustrations.)

SUPERSONIC vibrations with frequencies beyond the audibility limit, i.e. above 20,000 c./sec. can be generated in fluids and in solid bodies by various means, but piezo-electric and magnetostrictive methods are most generally used for this purpose.

A quartz plate situated in an electric field will expand or contract according to the field's direction. In an alternating electric field quartz can thus be made to vibrate and if it is immersed in a fluid or pressed against a solid body its mechanical vibrations will be transmitted to the medium with which it is in contact. Maximum amplitudes will occur when the forced frequency of the electric field is nearly in resonance with one of the natural frequencies of the crystal. Higher frequencies can be achieved by using thinner quartz plates, the upper limit being at about 1,000 Mc./sec., beyond which the mechanical strength of thin plates is no longer sufficient.

The magnetostrictive method which can only be used in practice up to 60 kc./sec. is based on the fact that a bar of ferromagnetic material will contract somewhat when placed in a magnetic field, the maximum amplitude in an alternating field being reached under resonance conditions. The bar is usually of nickel, which is chosen because of its considerable magnetostrictive effect.

The supersonic receivers work on the reversed effects. When supersonic waves impinge upon a crystal, they cause periodically alternating charges to appear on the plate's surface, and these can then be amplified, rectified and registered by an indicator instrument. In the same way a magnetostrictive transmitter can also work as a receiver; the supersonic waves cause periodical expansions and contractions of the nickel bar, and the induced currents thus generated in the windings around the bar can also be amplified, rectified and registered by an indicator instrument.

The relation between the phase-velocity V, frequency f and wave-length λ of a progressive wave is expressed by $V = f\lambda$, and as the speed of sound varies, the wave-length at a given frequency will also vary according to the substance through which it is propagating. For instance in steel, where V = 5,000 metres/sec., the wave-length in the frequency range of 2×10^4 — 10^7 c/sec. will vary between 25 cm. and 0·05 cm., whereas in air the corresponding numerical values are approximately 15 times smaller (see Table 1).

TABLE 1

Medium	Velocity (m./sec.) $V = \sqrt{E/\rho}$	Wave-length (cm.) $\lambda = V/f$ f = 435 (*)	f = 20,000	$f = 10^7$ c/sec.
Dry air, at 0 deg. C.	331·7	λ = 76·25	1·6585	0·003317
Water, at 20 deg. C.	1,470	337·93	7·3500	0·014700
Glass	4,650	1,068·96	23·2500	0·046500
Hard rubber	1,571	360·92	7·8500	0·015700
Cork	500	114·94	2·5000	0·005000
Steel	5,000	1,149·42	25·0000	0·050000
Iron	5,170	1,188·50	25·8500	0·051700
Aluminium	5,040	1,158·62	25·2000	0·050400
Copper	3,710	852·87	18·5500	0·037100
Brass	3,300	758·62	16·5000	0·033000

(*) for gases $V = \sqrt{\frac{c_p \cdot p}{c_v \cdot \rho}}$

The very small wave-lengths achievable with supersonic frequencies are the main reason why they are used for the non-destructive testing of materials.

Furthermore these very short wave-lengths make it possible to send out parallel beams of supersonic rays. Quartz plates vibrating at high frequencies send out sonic rays which are all the more easily radiated in a given direction the smaller the ratio of wave-length to plate radius. If α is the aperture angle of the cone in which the sonic waves are emitted (Fig. 1), then the relation for a circular source is:

$$\sin \alpha = c \cdot \frac{\lambda}{r} \quad (c \simeq 0{\cdot}65)$$

and this equation shows that if a source of sound has a diameter equal to or smaller than the wave-length, in the case of a two-side radiation the sonic rays will be emitted in all directions and are practically spherical waves. This is the reason why audible sounds can only be imperfectly directed even when considerable accessory equipment, such as horns, etc., is used. Taking for instance a source with r = 1 cm. and a frequency of $2{\cdot}5 \times 10^6$ c/sec. which corresponds to a wave-length of approximately λ = 0·2 cm. in steel, the angle α = 8 deg. so that radiation on one side will practically occur only through a cone with a 16 deg. aperture.

When sonic waves of any given wave-length and with an energy E impinge upon the boundary surface of two media (Fig. 2), in general a fraction E_r of the total energy E will be reflected, while the remaining energy E_d will go through it. The reflection coefficient, defined as the ratio $R = E_r/E$, depends in the case of vertical incidence mainly on the difference of the so-called sonic resistances $W = \rho \cdot V$ (where ρ = density, V = sonic velocity) of the two media. The more different the sonic resistances of two media are, the greater the reflection coefficient R will be; for instance on the boundary surface between a solid body and a gas nearly all the sonic energy will be reflected.

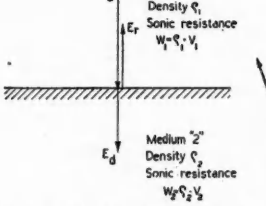


Fig. 2. **Behaviour of sound at the boundary surface of two media.**

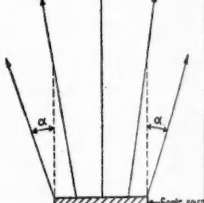


Fig. 1. **Sonic radiation of a circular source of comparative small wave-length.**

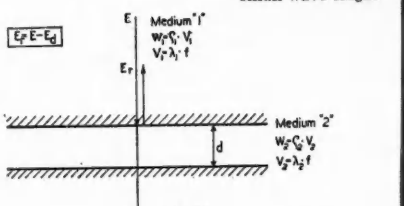


Fig. 3. **Insertion of a medium "2" in a medium "1"**

For materials testing the case shown in Fig. 3 is of particular importance, although it cannot be treated in quite the same way as the case of a single boundary surface. The media "1" are more or less mechanically coupled together by the thin intermediate layer "2"; experimental and theoretical investigations have shown that with air as the intermediate layer:

1. R is very large, when $\lambda_2 \ll d$;

2. R is still very large, when $\lambda_2 \cong d$;
3. R is still noticeable, when $\lambda > 100\text{-}500\ d$;
4. $R = 0$ when $\lambda_2 \gg d$, or when it happens that

$$n\frac{\lambda_2}{2} = d \quad (n = 0, 1, 2, \ldots)$$

If for instance the air gap d of a fatigue fracture is estimated at about 10^{-3} mm., then R will still be noticeable when $\lambda_2 = 0{\cdot}5$ mm., whereas for instance with a usual testing frequency of $2{\cdot}5 \times 10^6$ c/sec. for air $\lambda_2 = 0{\cdot}12$ mm., which is thus less than the minimum required. With solid or liquid intermediate media the conditions are correspondingly less favourable owing to the smaller difference between sonic resistances.

Furthermore it should be mentioned that the ratio of the wave-length to the transverse dimensions of the intermediate media is also of importance. If these are comparable to, or smaller than, λ, the sound will be diffracted around the edges of the outer medium with the result that the reflection required to reveal the existence of an intermediate medium will be too small.

Supersonic waves can be used for the non-destructive detection of cracks, cavities, porosities or foreign matter which are in the material under investigation, part of the sonic energy being reflected so that the sonic intensity going through the material will be reduced. Flaw-detection can be achieved either by measuring the sonic energy coming through, with the transmitter and receiver units at two oppositely situated parts of the test-piece, or by determining the reflected energy with both the transmitter and the receiver on the same side of the test-piece.

In the latter case the sonic waves reflected by the flaw must be differentiated from those due to the external boundary surfaces, and this is achieved by a method similar to that used for the echo-fathoming of sea-beds, inasmuch as instead of continuous wave-trains very short supersonic pulses are directed into the test piece, and the time taken by the reflected pulses from the flaw and from the opposite wall can then be observed on an oscilloscope screen.

Both methods are used in practice, although the echo-sounding system probably is generally the more efficient.

Cavity in a steel block: The block was investigated with supersonic rays in the A-B direction at various levels (Fig. 4), and the sonic intensity passing through the block was registered at each level; the intensity-curve of Fig. 4 was thus obtained. After sectioning the block horizontally in two at the depth "Z" at which sonic intensity reached its maximum level, and then cutting it longitudinally through the cavity, it was found that the section determined by the supersonic process coincided exactly with the lower end of the cavity.

Welding joints: The supersonic inspection of welding seams is still in the development stage but the results obtained seem to show good possibilities, and the method used is illustrated in Fig. 5 for the case where

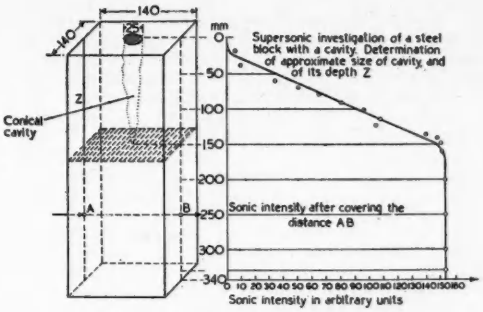


Fig. 4. **Investigation of a steel block.**

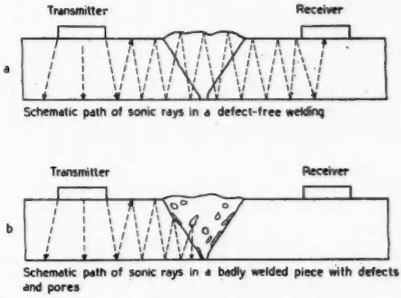


Fig. 5. **Supersonic inspection arrangement for welding seams.**

only one surface of the material is available for inspection, as for instance in welded pipes, containers, etc. for which an X-ray inspection would not be possible. A perfect welding seam lets practically all the sonic energy pass through undiminished (Fig. 5a) so that sonic waves will reach the receiver even after going through a complicated zig-zag course; whereas a porous or badly made welding seam (Fig. 5b) will more or less "screen" the receiver from the sonic waves as a result of the considerable number of reflections during which energy is lost as mentioned above.

In using the depth-sounding method the sonic conditions were found to be so complicated that the actual echo-fathoming method could not be fully applied. with the result that diagrams were mainly assessed by considering the amplitude of the pulses. Large amplitudes signified good sonic permittivity of the welding seam, and low amplitudes a low permittivity. The comparison with corresponding X-ray photographs shows good agreement between both methods.

FRANCE

ELECTRONIC HEATING APPLIED TO THE THERMAL TREATMENT OF WOOD, RUBBER, AND PLASTIC MATERIALS

By M. DOUCERAIN. (From *Bulletin de la Société Française des Électriciens*, Vol. 6, No. 62, October, 1946, pp. 498-509, 18 illustrations.)

ELECTRONIC heating of a material is achieved by using the material to be heated as a dielectric in a condenser connected to a source of high-frequency current. The condenser then works as a reactance with a parallel resistance. In electronic heating the heat is thus developed within the molecules themselves as the current passes through the material, instead of being obtained by radiation, conductivity, or convection.

Assuming the material to be a perfect thermal insulator, the time required for it to reach a given temperature is independent of its dimensions and of the temperature of the ambient medium, and only depends on the intensity of the current. The temperature is reached simultaneously and is the same at all points of the body irrespective of its dimensions. The efficiency of the energy transformation is equal to unity.

An imperfect thermal insulator can artificially be converted into a perfect insulator incapable of yielding the energy within it, either by having the temperature of the ambient medium equal to that which is to be

reached, or by providing for a heating period of such short duration that no energy is radiated from the body. Thus there will be no temperature gradient from the centre of the body outwards, although such gradients are necessary in certain cases, e.g. for evaporation, or for the manipulation of pre-heated plastic forms.

When a dielectric mass is placed between the two plates of a condenser, the electric field due to the different potentials of the plates will cause a displacement of the molecules of the dielectric. In non-polar molecules the positive nuclei are shifted towards the negative, and the negative charges towards the positive plate. The charges return to their original positions when the electric field disappears. In polar molecules with dipole moments, i.e. positive and negative charges which do not coincide in the equilibrium condition, the dipoles are rotated by the electric field into the field vector direction, in the same way as magnets placed in a magnetic field.

The work performed by the electric field in displacing the electric charges is converted into heat as the charges resume their equilibrium position when the field becomes zero. Heat development depends on the resistance of the molecules to this displacement, and the resistance is due to the intermolecular field. The relaxation period of the molecule determines the time taken by the temporarily unbalanced atom to return to its equilibrium position.

The amplitude of the displacement of positive and negative charges from the centre of gravity of the molecule is characterised by the dielectric constant or specific inductive capacity of the substance, and the work per unit volume, i.e. the heat generated in the substance is given by the loss factor, $K \tan \delta$, where δ is the loss angle.

Resistance to displacement of the electric charges in the dielectric is greater, the greater the frequency of the current causing this displacement. The dielectric constant K remains constant only up to a certain frequency and then drops down to zero ; this is because with increased frequencies the displacement of the electric charges is not complete but lags somewhat behind the impulse which creates it, and thus heat is generated.

The dielectric constant and the loss angle vary with temperature at a given frequency, as the displacement of the dielectric charges is limited by the resistances due to the internal friction, or viscosity, of the substance, which is a function of temperature. In Fig. 1, the curves of K and tan δ for glycol phtalate are plotted as functions of temperature for the two frequencies 50 and 50×10^3 c./sec. At first K has a low and fairly constant value ; beyond 50 deg. C. it rises rapidly and then decreases owing to the molecular dispersion created by the temperature rise which acts more or less transversely to the electric field, so that K instead of retaining its maximum value will tend to decrease as temperature increases. The K and tan δ curves for a mixture of rubber and sulphur are given in Fig. 2, with 12 per cent and 23 per cent of sulphur in the vulcanisable mixture, and frequencies of 60, 10^3, and 10^5 kc./sec.

The dielectric constant also varies according to the heterogeneity of the material. A complex material can be regarded as an assemblage of particles of different sizes and different dielectric constants, and each of these particles can be regarded as a condenser with a parallel resistance. In an electric field the terminal contact surfaces of these elementary condensers will have different potentials, and the resulting currents on surfaces of various resistivities will be the cause of heat.

Heat is also generated by ions in the impurities between these particles, which start moving under the influence of the electric field and their resistance to this motion also generates heat. In a damp body, for instance, in which the dielectric constant of the dry substance is 5, and that of water 80, the high potential

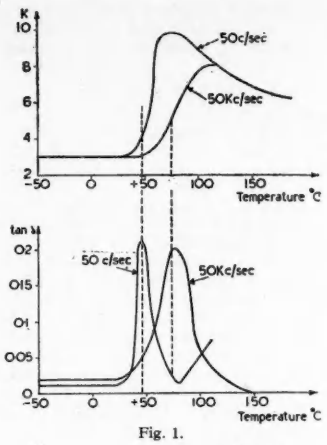


Fig. 1.

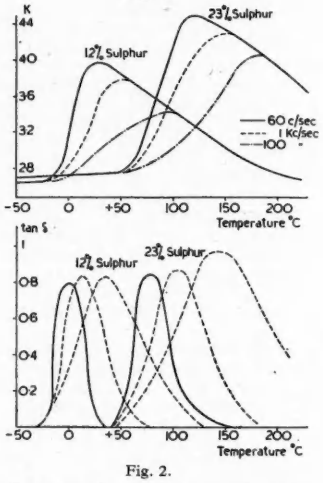


Fig. 2.

differences between the particles create comparatively strong currents and therefore a high loss angle. In Fig. 3a the variations of the dielectric constant of a vulcanisable mixture are given as functions of the percentage of sulphur, for temperature parameters of 25 and 150 deg. C., respectively, whilst Fig. 3b shows the variations of tan δ for damp wood (maple, mahogany, and pinewood) in terms of the percentage of humidity.

Calorific energy is thus formed in three different ways : within the atom, by deformation of the electron orbits ; within the molecule, in the case of polar molecules with an electric dipole moment ; and in the particles of a heterogeneous substance, this being the most usual case.

CALCULATION OF THE QUANTITY OF HEAT REQUIRED.

The work done in displacing the electric charges in an electric field is given by

$$W = a H^2 V f K \tan \delta \quad .. \quad .. \quad (1)$$

where a = a constant, H = electric field strength (volt/cm.), f = frequency (c./sec.), K = dielectric constant, δ = loss angle, and V = volume (cm.^{3}). If the thickness of the material is d, and plate potential, U, then calorific power will be proportional to $H^2 = (U/d)^2$. H is limited by the breakdown voltage ; in practice must be less than 800 volts/cm. for porous, and 2,000

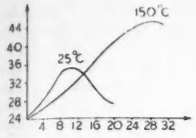


Fig. 3a

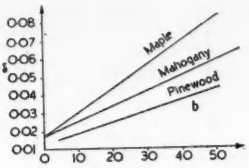


Fig. 3b

volts/cm. for non-porous materials. As the dielectric constant K depends on the frequency, the capacity $C = KA/4\pi d$ will also vary with frequency, and C_{max} will be a definite value corresponding to K_{max}.

The power required depends on the volume (and hence on the mass) of the material to be heated. The power available increases with frequency, which should therefore be chosen as high as possible. However, with the generating circuits so far developed, the choice of the frequency is governed by the power required, as the maximum power-output of a generator is limited at higher frequencies.

Frequency	Maximum power generated
10 Mc./sec.	300 kW
20	200
30	50
600	2
2,500	0·35

Furthermore, the dimensions of the electrodes should be smaller at higher frequencies. For an electrode of given dimensions, the greater the frequency, the greater the probability of an unequal distribution of potential over the surface, owing to the effect of stationary waves. To avoid this, the distance between the plates, and also the maximum electrode dimension, should be smaller than 1/16th of the wave-length used ; this gives the condition :

$$d < \frac{1875}{f\sqrt{K}}$$

where d is in cm., and f in Mc./sec. Fig. 4 is a chart giving the value of d_{max} in terms of f when it is required that the variations of field strength H should be less than 10 per cent between the electrode extremities.

In some cases the material is placed between the condenser electrodes with a layer of air on either side ; the potential drop in the material is then

$$U_1 = \frac{U}{1 + \dfrac{K_1 d_1}{K_2 d_2}}$$

where $U = U_1 + U_2$, K_1 = dielectric constant of the material, K_2 = dielectric constant of air, d_1 = thickness of material, d_2 = thickness of air layer. In the case of irregular shapes, the potential difference applied should be proportional to the thickness of the dielectric (see Fig. 5). This can then be achieved by using complementary forms (5a) with similar dielectric constants but lower losses (Fig. 5b), so that the field will pass through a constant cross-sectional area of dielectric ; another solution is to give the upper electrode a certain slope relative to the lower electrode, so that $d'/d = K/K'$. Where a non-uniform field distribution is required to concentrate heat at certain parts of the material, specially shaped electrodes will be necessary.

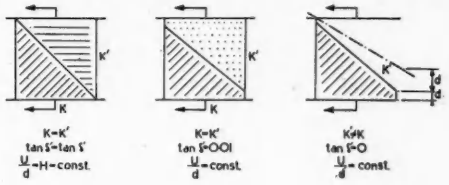


Fig. 5

ELECTRODYNAMIC FORMULAE.

The material being heated can be regarded as a condenser with a parallel resistance. Then

$$W = UI_r = 2\pi f CU^2 \tan\delta = 2\pi f C_0 U^2 K \tan\delta$$

but $C_0 = aA/4\pi d$ so that

$$W = 2\pi f a \frac{A}{4\pi d} U^2 K \tan\delta$$

$$W = \frac{1}{2} a V \frac{U^2}{d^2} f K \tan\delta = \frac{1}{2} a H^2 V f K \tan\delta \quad (2)$$

and this expression (2) is similar to formula (1).

The voltage, power, and frequency required to obtain a certain temperature rise during a given time interval can be determined from the following formulae when the dimensions, the specific heat, the dielectric constant, and the loss angle of the material are known : dimensions = V ; power $W = 4{\cdot}18 \times \frac{Vc\,\Delta T}{\Delta T}$; reactance $X_C = 1/2\pi f C$; equivalent resistance $R_C = X_C \cdot \cos\varphi$; current $I^2 = W/R_C$; applied voltage $U = IR_C$.

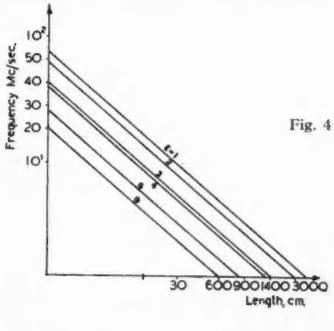


Fig. 4

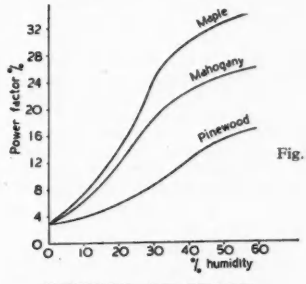


Fig. 6

DRYING OF WOOD.

Dielectric heating is only interesting when the thickness of the wood is such that heating by conduction methods gives insufficient results. As the dielectric constant of damp wood varies linearly as the percentage of humidity decreases, the power must be regulated to avoid internal carbonisation of the wood (see Fig. 6). There are two possible methods :

1. The load is fixed between two pressing plates. The capacity of the dielectric varies from the beginning to the end of the drying operation, since K is a function of the humidity percentage, and therefore a compensating arrangement will be necessary to provide constant tuning. Furthermore the thickness of the dielectric should not be too small as this would give rise to

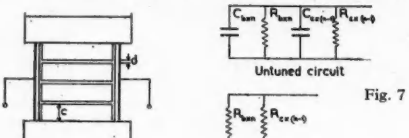
excessive reactance values which would make it practically impossible to tune the primary oscillating circuit. If the charging condenser is in the primary oscillating circuit, then its initial and final capacities must be within the limits of the oscillating range of the electronic valve used; if the condenser is in a circuit coupled with the oscillating circuit, resonance will only be maintained by varying the impedance of the coupled circuit.

2. Load moving freely between the condenser electrodes. The material comes in damp and goes out dry; its mean dielectric constant is constant, the impedance has a fixed value and tuning compensation is not required. This method is more advantageous; for instance, 35 kilowatts of high-frequency power are necessary to reduce the humidity of 1,500 kg. of wood from 50 per cent to 10 per cent in 10 hours.

GLUING OF WOOD.

For longitudinal heating (Fig.7), the electrodes are arranged perpendicular to the plane of adhesion, and the circuit is equivalent to a group of parallel condensers and resistances. For transverse heating (Fig. 8) the electrodes are parallel to the planes of sticking, the circuit is equivalent to a group of condensers and resistances in series, the tuned circuit being a purely resistive circuit.

Fig. 7



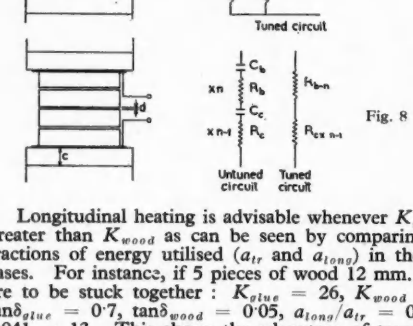


Fig. 8

Longitudinal heating is advisable whenever K_{glue} is greater than K_{wood} as can be seen by comparing the fractions of energy utilised (a_{tr} and a_{long}) in the two cases. For instance, if 5 pieces of wood 12 mm. thick are to be stuck together: $K_{glue} = 26$, $K_{wood} = 5$, $\tan\delta_{glue} = 0{\cdot}7$, $\tan\delta_{wood} = 0{\cdot}05$, $a_{long}/a_{tr} = 0{\cdot}535/0{\cdot}041 = 13$. This shows the advantage of transverse heating. With dielectric heating at high frequencies, the heating time is proportional to the volume, e.g. 25 watts are necessary to raise the temperature of 1,000 cm.³ of wood with 35 per cent humidity by 100 deg. C.; whereas with conduction heating, using a press and heating plates, the heating time depends on the square of the thickness, e.g. 4 minutes for 12·5 mm., and 16 min. for 2·5 mm. Furthermore high-frequency heating ensures a uniform heating of all layers. To avoid a cooling of the outer layers through radiation, insulating materials or heated plates may be added. The adhesives used are based on synthetic resins, phenol formol, urea formol, resorcine, vinyl resins, etc. For instance an adhesive of the urea type will seize at 20 deg. C. in 8 hours, and at 70 deg. C. in 8 mins. Phenolic synthetic resins permit the sticking of wood with variable degrees of humidity.

For plywood shapes, a special high-frequency gun is used. This gun is fitted with a trigger-released pin which works as a circuit-breaker. The lines of force are concentrated in the plane of sticking which has a higher dielectric constant. The gun is a low-voltage ultra-high-frequency gun (200 Mc./sec.). The sheets are first covered with adhesive made from synthetic resin, and the first lamina is applied and held on the form with pincers (Fig. 9). The second lamina is applied on the first by means of adhesion points obtained with the high-frequency gun and spaced in such a way as to overcome the natural rigidity of the lamina, each point requiring 1-2 sec. for good adhesion. The pincers are then removed and the rigid assembly is covered by another form; after tightening with braces, the high-frequency current is applied and adhesion will be complete in a few minutes. This process can be used for aircraft fuselages, box spars, leading edge sections, curved doors, etc.

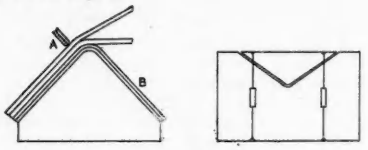


Fig. 9

Impregnated rubber. The timber is first dried and then impregnated with a solution of phenol plastic resin under pressure; it is then dried again, cut into shapes which are put into forms under a pressure of approximately 300 kg./cm.² and finally subjected to high-frequency heating. As synthetic resins have a high internal friction coefficient, i.e. a high damping capacity which is the cause of the dielectric losses, they are a suitable substance for dielectric heating.

Rubber. Pure rubber at 20 deg. C. has a dielectric constant of about 2·4, and it has very low losses; but the vulcanisable mixture consisting of pure rubber, sulphur, an accelerator, and various additional components, has considerable dielectric losses. It also has a very low thermal conductivity; thus high-frequency will be increasingly efficient with greater thicknesses of material. For instance, a cylinder 10 cm. in diameter and 6 cm. high placed between plates heated to a temperature of 135 deg. C. will only reach 120 deg. C. in its centre after 1 hr. 30 min., whereas with high-frequency heating a uniform temperature of 140 deg. C. throughout the material can be attained in 15 min. The temperature of 1 dm³ of a vulcanisable mixture subjected to high-frequency heating will rise at a rate of 10-15 deg. C. per minute with a power of 300 W. and a frequency of 10 Mc./sec. Furthermore 1 kg. of the mixture can be vulcanised at 140 deg. C. for a total cost of 300 W-hr. low-frequency; 200 W-hr. being required to reach the vulcanisation temperature of 140 deg. C. in 12 min., and 100 W-hr. applied intermittently thereafter to compensate the calorific losses.

During vulcanisation rubber passes from a plastic to an elastic state at 143 deg. C., and high frequency is used for pre-heating purposes, the mass being placed in a press with plates heated up to the reaction temperature. Rubber tyres, belting, and rollers for printing, etc. can be vulcanised in this way.

High-frequency heating is then also applied to the vulcanised rubber for regeneration up to 200 deg. C. approximately, and large pieces of rubber can thus be treated without the necessity of dividing into smaller parts with a greater total heating surface. The crude rubber is subsequently heated up to depolymerisation temperature before going to the mixer.

Plastic materials. Phenol plastic resins and polyvinyl chlorides, as well as acrylic laminates and cellulose acetates used for large-size laminated insulators can also be advantageously treated with high-frequency heating. Electronic heating has a wide range of applications, for instance, in making gear-wheels, bearings, and bakelite-paper boards, in drying foodstuffs, destroying ferments in vegetables, and sterilising products already in a (cellophane) wrapping; it also makes possible the dehydration of fragile substances, such as vitamines and fermentation agents, under vacuum and low pressure conditions. Thus high-frequency heating enables heat to penetrate to the core of the material, and it can be used in conjunction with all other heating methods which will then be employed to prevent dissipation of internal heat.

STANDARD SLAG AND CLINKER UTILISATION WORKS

By G. G. ZELICHENOK. (From *Mehanizatsia Stroitelslva*, No. 3-4 and No. 5, 1946, pp. 11-15 and pp. 6-7 respectively, 8 illustrations.)

A BRANCH of the Russian Ministry of Constructional Machinery has designed a number of "Standard Works" for such manufactures as cinder-concrete blocks, blast-furnace cement, gypsum products and slag wool. They are scientifically designed and special machinery has been developed where necessary to meet their exact needs. Quite a number are already in operation or in the course of construction. We give below brief particulars of three such "Standard Works."

I. CINDER-CONCRETE BLOCK WORKS.

Boiler cinders are used, with additions of caustic lime, cement and clay. The basic output is 10,000 hollow blocks a day (2 shift, 16 hours) measuring 16 × 7·7 × 8·5 in., but the machinery can also be used to turn out solid blocks, halves, quarters, etc.

The area covered is 4·7 acres, almost half of which is a cinder dump as shown in Fig. 1. Transportation is by conveyor belt for loose material and trolleys for individual items, but this does not cover the method of transportation of cinders to and from the storage dump which is not standardised and is done in various ways.

The operations performed may best be followed with reference to the diagram Fig. 2.

The cinders arrive at the railway siding (24 on the right hand side of the diagram) are dumped at (1) and subsequently loaded by a grab (2) or otherwise into a hopper (3) whence they are fed through feeder (4) to elevator (5). They are screened and magnetically separated at (6) and the larger pieces are directed to the crusher (7) and back to the elevator while the rest travels on a conveyor (8) to the mixing room at the top of the main building. Here they are measured off into tipping wagons (15) and taken to the mixing chute (16) where cement is added. The cement reaches this point via hoppers (9 and 9) and elevator (12) from railway trucks (24 on the left of diagram) from which it is unloaded by Clarke scoop. The liquid additions are made through a pipeline (13) and tank (14) and the mixing is done in the mixer (17). The blocks are moulded, two at a time, in an automatic vibrating moulding machine (19) and taken by trolley (20) into the steam ovens (21), (22) is the cooling room and (23) the storage dump for the finished article.

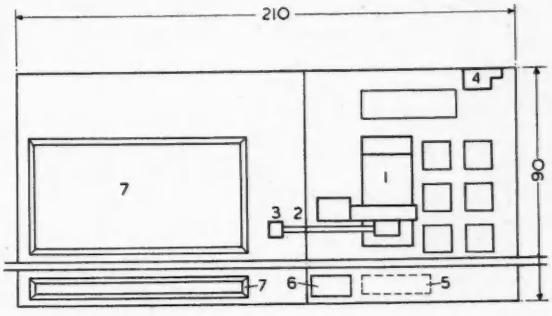


Fig. 1.

1. Main plant building
2. Gravity conveyor
3. Crushing plant
4. Office
5. Wet admixious plant
6. Coal dump
7. Cinder dump

The moulding machine has a capacity of 300 blocks per hour, the mixer of 1·3 cub. yd. There are 14 steaming rooms each of 720 block's capacity, with an estimated steam consumption of 18 lb. per cub. ft. of concrete. The standard composition of mixture is (per cub. ft. of finished material): 1·65 cub. ft. of cinders, 8 lbs. of cement, 4 lbs. of lime, 18 lbs. of water.

II. BLAST FURNACE CEMENT MILL.

This is designed for a two-shift output of 10,000 tons per year and is based on a standard rotary drying kiln 26 ft. long by 5 ft. 3 in. diameter, and a Kennedy rotary mill 12 ft. 9 in. long by 5 ft. 0 in. diameter. It can be used for making cement from several different types of raw materials, of which blast furnace slag and boiler ash are the most common, with such additions as lime, gypsum, portland cement, etc.

The standard layout, including storage space, occupies 1½ acres and is shown diagramatically in Fig. 3. All the operations are mechanised, involving 16 motors to a total installed capacity of 220 KW.

Estimated yearly consumption figures are :—

1. Slag (25 per cent moisture content) 11,625 tons
2. Unslaked lime .. .. 2,500 tons
3. Gypsum .. .. 500 tons
4. Coal (standard quality) .. .. 750 tons

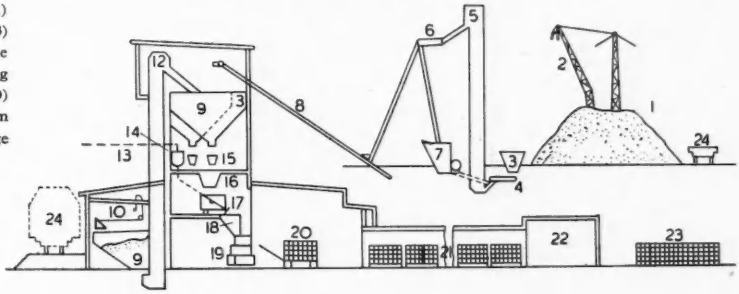


Fig. 2. **Cinder-Concrete Block Works.**

(1) Slag dump; (2) Derrick with grab; (3) Slag hopper; (4) Feeder; (5) Slag elevator; (6) Screen; (7) Crusher; (8) Slag conveyor; (9) Cement bunker; (10) Clarke scoop; (11) Screw feeder; (12) Cement elevator; (13) Milk of lime pipe line; (14) Milk of lime tank; (15) Dosing device; (16) Collecting funnel; (17) Mixer; (18) Hopper; (19) Moulding press; (20) Trolley; (21) Steam oven; (22) Cooling chamber; (23) Storage yard; (24) Railway truck.

1. Slag dump
2. Lime, etc. dump
3. Conveyors
4. Crusher
5. Vibratory screen
6. Slag bunker
7. Feed disc
8. Drying kiln
9. Cyclone
10. Elevator
11. Dry slag bunker
12. Admixtures bunkers
13. Kennedy mill
14. Filter
15. Belt elevator
16. Screw conveyor
17. Finished product silos
18. Screw conveyor
19, 20. Transport

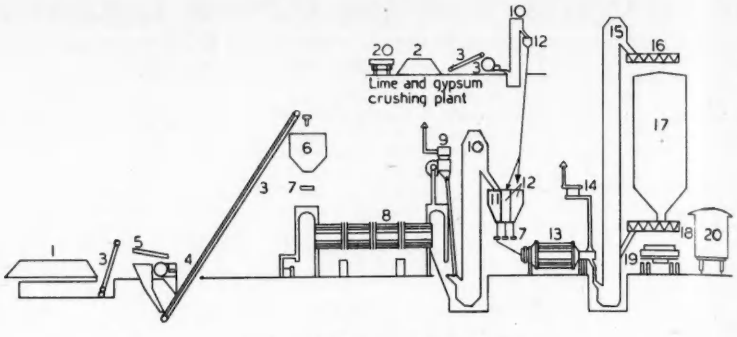


Fig. 3. **Blast Furnace Cement Mill.**

III. SLAG WOOL WORKS.

Mineral wool for thermo-insulating purposes can be obtained from a variety of natural minerals such as dolomite and various lime-stones; but metallurgical slag is usually employed.

The wool is somewhat uneconomical as regards transport and, where suitable raw materials are not readily available, it is better to set up local production on the basis of imported materials than to transport the finished product over large distances.

Slag wool production in the U.S.S.R. has been a long way from satisfying current demands (it is only 1/40 of that of the U.S.A.) and in considering the two alternative methods—steam blowing and centrifugal—it was felt that there has not been sufficient experience to decide in favour of one to the exclusion of the other.

Standard plants were, therefore, designed on the basis of both methods, one smaller and less mechanised (1,500 tons/year) on the centrifugal principle and one larger (4,000 tons/year) for steam blowing. The latter is shown diagrammatically in Fig. 4.

The slag (or natural mineral) is crushed and screened. Fine particles (less than $\frac{1}{8}$ in.) are sifted off and removed as refuse. The melting is done in a 30 in. diameter water-jacketed cupola of 1000 lbs. per hour capacity and the molten mass, at a temperature of about 1,500 deg. C., is squirted on to a jet of steam issuing from a V-shaped nozzle at a pressure of 100-112 lbs. per sq. in. This takes place in a " precipitation chamber " 52 ft. long by 6 ft. 6 in. wide by 13 ft. high with insulated metal walls and a floor which is made of metal netting and forms part of a conveyor system which carries the wool away for packing or further processing.

The speed of the floor is variable between 7 in. and 5 ft. per minute according to the thickness of the finished wool layer required, which varies from $\frac{3}{8}$ to $2\frac{1}{2}$ ins. As the wool emerges from the precipitation chamber it is passed over the mouth of a suction system which removes steam and air from the chamber at the rate of 66 cub. ft. per sec. It is then pressed down with a roller and cut up into sections as required: there are four disks for longitudinal cutting and an electric saw for cross-cuts.

The production of a ton of wool requires the use of 1·6 tons of slag and 0·3 tons of coke. The electrical installed capacity of the plant is 47 KW. When working on a 24 hour, three-shift basis it employs 32 men during the day and 17 during the other two shifts.

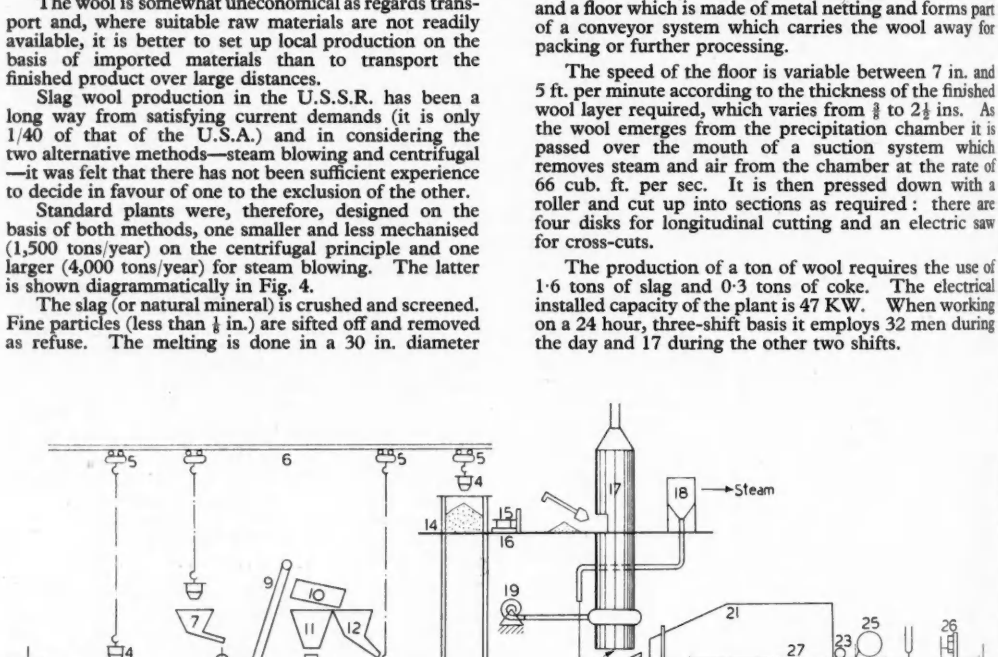


Fig. 4. **Slag Wool Works.**

(1) Railway truck; (2) Slag storage dump; (3) Coke storage; (4) Grab; (5) Overhead conveyor; (6) Conveyor rail; (7) Receiving hopper; (8) Crusher; (9) Conveyor; (10) Screen; (11) Waste hopper; (12) Crushed material hopper; (13) Truck; (14) Bin for raw material and coke; (15) (16) Weighing device; (17) Cupola; (18) Bitumen heating tank; (19) Air blower; (20) Steam nozzle; (21) Precipitation chamber; (22) Conveyor; (23) Roller press; (24) Conveyor; (25) (26) Cutters; (27) Intake of suction system; (28) Exhauster; (29) Table for preparation (working) of material; (30) Finished product.

ORGANIZATION REQUIREMENTS FOR SUCCESSFUL EXPORT BUSINESS

By G. WOLF, President, United States Steel Export Company, New York. (From *Mechanical Engineering*, Vol. 69, No. 1, January, 1947, pp. 26-28.*)

THE organization requirements for successful export business are no different as to fundamentals from those for any domestic business. However, since we are to consider the requirements for export, let us first take a careful look to see what foreign trade really involves.

PRINCIPLE OF TRADE BETWEEN NATIONS.

Foreign trade is based upon one fundamental principle and a few indispensible conditions. The author will attempt to establish this one fundamental principle, in the following way :

The various regions and nations of the world are not equally favoured by nature in potential wealth. The skill, proficiency, and aptitude for social organization and collective endeavours of their inhabitants differ widely.

Favourable climate, richness of soil, existence of minerals not found elsewhere, or their superiority in quality and concentration, adequacy of cheap and plentiful thermal or hydro-electric power, the fortunate location of resources with respect to each other and to the centres of production and consumption, facility of transportation, and other physical factors, render a region particularly adapted to the production of certain commodities.

On the side of human characteristics, marked proficiency of the labour of one country in special crafts, exceptional talents of its leaders for organization, management, and administration, healthy political environment, ability of its people, of all classes, to work together in a common effort for a common goal, are paramount elements in the determination of the fields of economic activity most appropriate for and most likely to be successful in that country.

The degree to which all those natural human as well as financial factors exist favourably and combine efficiently ultimately determines, for each area of the world, in what field of economic activity each nation can specialise to advantage. The fitness of a country to produce certain commodities or provide certain services is, in the end, evidenced by its ability to manufacture or supply them most cheaply.

Provided the exchange of goods and services is unhampered through the channels of international commerce and finance, the benefits that befall society through intelligently selected specialization of activities are immense. The volume of consumers' and producers' goods, which thus becomes available for the satisfaction of human wants, is vastly increased by the possibility of producing them where they can be supplied most economically, that is, in the largest quantity per unit of investment of labour, management, and capital.

The principle of specialization, however, should not be misconstrued as denying nations having no decided advantages in any field of production or service, any opportunity in participating in the productive cycles of the world.

From the point of view of the general welfare, it is desirable that a country devote its resources not only to the expansion of those enterprises for which it especially qualifies but confine these activities to lines where its comparative advantage in the cost of production is greatest. Reciprocally, unfavoured nations should limit manufactures to those fields where comparative disadvantage is smallest.

However, it may be wise at times for a nation to foster in their infancy undertakings having eventual economic potentialities or encourage uneconomic activities vital to its defense or protection.

Peoples of nations poor in resources will produce less wealth with their efforts than the people of rich nations, but if they avail themselves of the opportunities of foreign trade, the volume of goods available to them through exchange will be far greater than if they attempt to produce all things.

No nation is self-sufficient. Policies aimed at promoting self-sufficiency through artificial restraints and barriers to volume importation of needed or desired commodities, is detrimental to a country's welfare. They remove labour, management, and capital from the fields of activity conducive to the best return to the nation, breed wasteful economic processes, and increase costs of production, thus lowering wages, profits, purchasing power, and finally living standards.

INDISPENSABLE CONDITIONS AS BASIS FOR FOREIGN TRADE.

Now as to a few of the indispensible conditions as a basis for foreign trade :

Specialization is the necessary prerequisite of international commerce, but not sufficient unto itself.

To make the wheels of foreign trade turn, three other conditions must be respected : (1) The availability of the products to be exchanged abroad; (2) the possibility of settlement of international financial obligations resulting therefrom ; and (3) the ability of the end-consumers in importing countries to pay for the products imported.

Specialization selects the types of industries which can be economically established in a country, but does not determine the time at which these industries will actually begin to sell their wares abroad.

The point at which the real business of exportation will be initiated by the specialized industries is when a permanent excess of production over the domestic demand has been attained. Experience has indicated repeatedly that no industry looks for a stable export trade as long as the home requirements easily absorb output. Opportunistic export business, so common in the United States, contributes little firmness to the texture of international relations and is not worth considering.

The second condition establishes the ability of foreign importers to make payment in foreign exchange for the goods purchased without resorting to transfer of gold ; it reaffirms the necessity of the maintenance of the balance of the international payments of the trading nations. It is of importance further to point out that continued imports of gold, in payment of exports of goods and services, react unfavourably on the economy of both the exporting and importing countries, weakening the financial structure of the nation deprived of gold and eventually increasing the price levels in the exporting nations taking payment in gold.

The last indispensable condition of foreign trade relates to the ability of the ultimate consumers in the foreign markets to buy the commodities and services exchanged. To prevent imported goods remaining unsold on the merchants' shelves and services unutilized, there must be sufficient purchasing power in local currency and an over-all availability of foreign exchange to permit remittances to the originating country.

The physical and human conditions which determine the superiority of a nation in the production of some commodities and services internationally traded, usually are not restricted within the boundaries of a single nation but cover larger areas of the world ; hence with

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very few exceptions, of which diamonds is an outstanding one, competition remains open between a number of countries. Even when the production of a commodity is limited to a single nation, competition still exists between the various producers of that nation, unless the country is ruled by a regime of managed economy. So American manufacturers of steel, automobiles, electrical goods, etc., are highly competitive at home and abroad.

POSITION OF THE UNITED STATES IN FOREIGN TRADE.

In the three-quarters of a century preceding the last war sweeping changes occurred in the picture of the business relations of the United States with the outside world.

Prior to the depression of 1873, a persistent excess of imports characterised our merchandise trade, which was counterbalanced by heavy investments of foreigners. After the 1873 crisis, an excess of exports appeared, limited in the beginning but progressively swelling into rivers of American goods for export during the early 20's and late 30's.

The character of our international trade also underwent striking change. Raw materials and foodstuffs, which previously constituted the main classes of our contribution to the international movements of goods, were gradually replaced by semimanufactured and manufactured articles. The importance of Europe as a recipient of our products rapidly declined, while the Americas, Asia, and to a lesser extent, Africa, imported more and more of our products. On the other side of the balance, our imports, which in the early days were principally composed of finished manufactures, progressively changed to crude materials and semimanufactures. Europe lost its outstanding sales position and the Americas, Asia, and again to a lesser extent, Africa, emerged as important suppliers of our needs.

But one factor in this picture must be recorded and wisely considered. The physical volume of our imports of foreign goods did not, over this same period, keep pace with the rythm of our expanding economy.

The reason for this is not hard to discover, and though perfectly obvious has been completely overlooked, it is feared, and has led to much fallacious thinking and heaped much abuse upon America for not wanting to buy, but rather, and only, to sell, and sell, and sell.

Let us look at the facts.

Taking the year 1938, a good representative prewar year, 85 per cent of our imports by value were accounted for by only 100 items ; 41 per cent of our total imports, for a value of $800,000,000 were duty-free. Items on which the duty was nominal accounted for 32 per cent of our imports for a value of $618,000,000. Thus 73 per cent of our imports, again by value, in a normal year are not seriously affected by duty.

So when we talk of increasing our importations by lowering tariffs, we are talking about approximately 30 per cent of our total normal imports. To double our total imports means increasing this 30 per cent area sixfold.

WORLD ECONOMIC LEADERSHIP.

We, as a nation, have succeeded willy nilly to world economic leadership. The method by which we discharge this obligation will depend in no small measure upon our willingness to accept world leadership, especially in the spheres of international finance and service. One thing is certain, namely, that we cannot go on lending if we are not to be repaid. Unwise international loans enrich neither the one who gives nor the one who receives, and accelerates world misunderstandings that endanger world peace. Although loans of American money abroad may, at times, be essential to the over-all world economy, including our own, they are not a substitute for domestic imports of services as well as goods as providers of dollars ; often they delay the solution of problems instead of facilitating it.

Contrary to a deeply rooted common belief, not less erroneous for being of widespread acceptance, imports are more beneficial to the economy of a nation than exports. After all, the final purpose of organized industry and commerce is to place at the disposal of man the largest possible amount of needed and desired economic goods. This optimum level in the enjoyment of wealth can be attained solely through imports of foreign commodities and services. The prosperity of a nation is not measured by its accumulation of precious metals and currencies, but by the essentialities and amenities of life available to its people. Exports are of importance inasmuch as they contribute to provide the means for the procurement of both.

Despite wishful expectations, many of our foreign loans, outstanding and planned, may never be refunded, because of the inability of the borrowers to honour their obligations. It is worth considering if, in some cases, it would not be preferable to extend financial assistance by purchasing abroad a larger amount of commodities of which we could make tangible use, rather than by swelling the account of our receivable foreign assets ; especially so when our national resources begin to dwindle.

Some of the foregoing concepts have been consistently followed in our national policy of foreign trade ; some others have been temporarily or permanently obscured.

ORGANIZING FOR EXPORT BUSINESS.

Let us now consider those requirements of organization necessary for a successful export business, which after all is the subject at hand. It may seem trite to say that on the part of anyone organizing for export, there must be a full understanding of all the fundamentals affecting world trade, and a very particular and intimate knowledge of the special branch of export that is under consideration for entering or carrying on.

All too often, the objective or purpose of the organization is not well known or known to only a few. Let us examine by way of example, the objective of the author's company, which is as follows :

" To obtain as a minimum that share of all markets for the products sold, product by product, territory by territory, to which our capacity in relation to the industry as a whole entitles us, and, to accomplish this participation ratio through the exercise of judgment, so as to ensure the maximum continuing return on investment to the corporation."

After one knows what he is trying to do, then, in the light of all the facts it is possible to obtain, the organizer must proceed—and again there is no intention to be trite—by taking the following steps in the order given : (1) analyse, (2) organize, (3) deputize, and (4) supervise.

Whether it be organizing for export or for a domestic business, the steps are the same, and there are certain keystone principles of organization, which, if the resulting organization is to be sound, require careful adherence. These are (1) leadership, (2) delegation, and (3) function definitions.

" Leadership " represents authority. It must possess all the authority necessary to exercise its leadership. It must likewise possess all the attributes of intelligence, integrity, and capacity in sufficient degree to warrant the authority given to it.

" Delegation " is the centre of all processes in formal organization. In essence, it involves a double responsibility. The one to whom authority is delegated is responsible to his superior for doing the job, but the superior remains responsible for getting the job done.

" Function definition " is the form in organization that assigns all functions, and is the organizational method through which leadership delegates to each subordinate his own specific task. Functions may be

unlimited in number, according to the procedure necessary to attain the given purpose. Formal correlation of functions is the task of the "organizer." His job is to correlate duties as such. Correlation of spirit is the responsibility of the "leader." He correlates the people who perform these duties.

These facts show the importance of understanding the formal principles of organization. However, not until there is a general understanding of the common purpose can there be that real and horizontal correlation which is the final test of a truly efficient organization. It is the duty of leadership to attain complete correlation of functions.

Staff service in organization means the service of advice or counsel, as distinguished from the function of authority or command. This service has three phases, namely, the informative, the advisory, and the supervisory.

There are two prime requisites in efficient staff service, co-ordination and infiltration. The term "co-ordination" describes the necessary method of sound staff procedure, but "infiltration of knowledge" is the ultimate purpose of all staff activities. Staff service is not alone for the top leader. It comes to him first for he needs it in the making of his own decisions. But the subordinates also need it in the execution of their responsibilities.

It is not alone the leader who has important things to tell his subordinates. These subordinates likewise have important things to tell the leader—things he should know in the exercise of his leadership. Also, they have important things to tell each other. This mutuality of things to be made known runs through all relations of superiors, subordinates, and equals throughout the organization. The infiltration of the true service of knowledge cannot be conceived as merely moving from the top—downward. No organization can be truly unified in spirit until it has evolved a similar service moving from the bottom—upward. Only when all have the right to be heard through an organized machinery for the expression of such right, as a stimulus to its exercise, can there be a truly informed leadership.

SUMMARY.

To summarize, top-management organization planning for successful export business involves the same principles and their careful application as does any other group effort. Since export involves not only domestic considerations but world considerations also, export business, especially under present and foreseeable future conditions, involves many added complexities requiring an automatic organizational vigilance and intelligence for the detection, interpretation, and adaptation of organizational procedure and action, lest these ever-shifting "rules of the game" completely confound and frustrate one's efforts.

Today, all the world looks to America for credit, for materials, for know-how.

How long will the world sellers' market continue for the United States? How long should it? We cannot go on selling in endless volume if there is no prospect for a final balance in our international payments.

This gets down to each organization engaged in export business, having within its own organization the means for proper evaluation of the risks involved in doing international business in a topsy-turvy economical political, and social world.

U. S. A.

QUICK ANALYSES OF MAGNESIUM FOUNDRY HEATS

By F. R. Bryan and G. A. Nahstoll. (From *Materials and Methods*, Vol. 25, No. 2, pp. 90-92, 4 illustrations.)

The accurate analysis of foundry heats to determine whether alloying elements are present according to specifications, or whether certain impurities are within required limits, is an important part of the procedure ensuring satisfactory castings. Control analyses must be made quickly since the cost of holding hot metal is high. In the case of the magnesium foundry it is doubly important that results be obtained as rapidly as possible, since time and temperature of holding are important factors in the control of grain size in the casting.

Combined with this need for quick results is the necessity for handling a large number of samples. While the number of heats will depend upon the size of the foundry and type of equipment it uses, even a foundry of moderate size will find the services of several analysts necessary. Wet methods of analysis are too slow for control of heats before pouring in most cases. The spectrograph, although expensive, has shown itself to be a valuable instrument in that both speed and a large volume of work can be obtained.

While spectrographic analysis by the usual methods, involving photographing spark spectra and determining the quantities of elements present from the intensity of typical lines, affords a considerable saving in time over wet chemical methods, it is still a difficult matter to get results to the foundry while a heat is being held preparatory to pouring. At the Ford Motor Co. a direct reading accessory was developed for the spectrographic control of magnesium foundry heats, making possible results within a few minutes, and the handling of a large number of samples by a single operator. As many as 80 determinations an hour could be analysed to an acceptable degree of accuracy by one technician, with an additional saving in cost of film and darkroom supplies.

The direct reading spectrographic method of analysis was developed within the Chemical Engineering Research Dept. of the Ford Motor Co. Analyses had previously been made with a Bausch and Lomb medium quartz spectrograph and a Feussner interrupted high voltage spark source using the usual photographic plate processing equipment and a non-recording microphotometer. For the direct reading the spark source was retained without alteration, while the spectrograph was modified by constructing an arrangement of photocells to replace the photographic plate. The processing equipment and microphotometer were no longer required. By placing slits to isolate certain selected lines of the spectrum, mounting one phototube to permit it to be moved into a position before any one of the slits, and using a second tube as a reference, the relative intensity of any selected line of the spectrum was then determined by voltmeter readings. The difference in potential between the movable tube and the reference tube was calibrated to read percentage composition on a meter scale.

Before the method was accepted for production analyses, tests were made to determine the reproducibility of results obtained. Determination of aluminium in magnesium was selected. Using standard alloys, the movable tube was positioned at 2373 Angstroms, and the fixed tube at 3176 Angstroms for reference. The alloys were sparked 10 times over an 8-hr. period without adjusting the instrument during that time. Later, about 15 determinations were made over a period of

two weeks, again without adjustment during the time of test. Results were :

	Std. 5·9 per cent Al		Std. 8·7 per cent Al	
Eight-Hour Test :	Max.	Avg.	Max.	Avg.
Deviation from mean per cent aluminium	0·15	0·08	0·13	0·06
Per cent deviation	2·50	1·30	1·50	0·70
Two Week Test : Deviation from mean per cent aluminium	0·18	0·12	0·28	0·13
Per cent deviation	3·10	2·00	3·30	1·50

The accuracy of the direct reading method was next checked against the photographic plate method. The average deviations between the two methods, for the eight constituents were :

Aluminium	0·17	per cent
Zinc	0·24	per cent
Manganese	0·02	per cent
Silicon	0·02	per cent
Copper	0·002	per cent
Nickel	0·003	per cent
Iron	0·003	per cent
Lead	0·02	per cent

Seven of these samples were checked by wet chemical methods for the three major elements. The average deviations were :

Aluminium	0·15	per cent
Zinc	0·17	per cent
Manganese	0·02	per cent

These deviations are of a similar order to those obtained in comparison of the direct reading with the photographic methods.

In use with production samples, it has been found possible to make determinations of the eight elements sought during a sparking time of 4 min. Use of a motor to drive the movable tube will permit more time at each position, and so increase the accuracy of the determination, without increasing sparking time per sample. One technician can at present make 80 determinations per hr. while, with two men, the samples can be analysed at the rate of 100 determinations per hr.

An ingenious method of preparing the alloy samples for sparking has resulted in reducing the time needed to bring the samples to the instrument. Molten metal is drawn into a Pyrex glass tube by means of a suction gun and upon almost instantaneous cooling, the glass is broken away. A rod of metal of correct size for sparking is thus obtained directly from the molten metal in the heat.

U. S. A.

LIQUID HELIUM

(From *Mechanical Engineering*, Vol. 69, No. 1, January, 1947, p. 40.)

ENTIRELY new vistas in the field of science—such as confirmation of the existence of a new kind of sound, a so-called " second sound "—are being explored in the Sloane Physics Laboratory at Yale University, New Haven, Conn., through extensive experiments with liquid helium.

Through the use of the liquid helium, it was revealed that temperatures within one hundredth of a degree of absolute zero, or approximately minus 273 deg. C., have been reached, as compared with the lowest temperature ever recorded on the face of the earth—minus 68 deg. C. in Siberia.

So low are the temperatures that iron and steel, at these temperatures, are transformed into substances which shatter like glass. Should a technician dip his finger into the freezing material used by the laboratory, the flesh would take on the gloss and brittleness of glass, and the finger would shatter to pieces if struck against a desk.

The so-called second sound—the existence of which was confirmed through the experiments with liquid helium—is described as essentially a temperature wave. It was detected by measuring the transmission of a fluctuating temperature through the liquid helium.

Whereas the speed of the normal sound wave in liquid helium has been put at roughly 700 fps., it is ascertained that second sound travels through liquid helium at a rate of approximately only 70 fps.

Second sound is inaudible to the human ear, although well within the normal range of hearing, and has a tonal frequency corresponding to about middle C on the piano. The new type of wave apparently does not occur in any other liquid except helium. Another puzzling quality of second sound is that it ceases when the temperature of the helium rises above 2·2 deg. C. absolute.

Although the practical uses of the research are entirely speculative, their scope covers many fields. For example, it is possible that a new alloy may be compounded which would reduce electrical resistance to a negligible quantity. Such a development would expand the area of electrical power transmission far beyond present limits and save billions of dollars in the electrical industry. Other researchers have applied the same fundamental investigations to the development of delicate heat-measuring devices. This work foreshadows much more precise knowledge of astronomical bodies. Low temperatures permit the Yale investigators to make studies of materials which otherwise would be blanked out by the reactions occurring in the presence of heat. The removal of heat in substances enables the scientist to study the material unhampered by interfering phenomena.

The fundamental theories behind all modern physical research, the " quantum mechanics " concept of the make-up of the universe, are the groundwork out of which the atomic bomb was developed. Whereas this concept so far has been confined to the study of the atom, it is suggested that investigation of liquid helium may permit pushing the results of atomic research into the field of larger masses.

Laboratory workers at Yale call helium a " magician's substance." A colorless watery liquid, it bubbles like a fine wine and gives off a " steam " when exposed to the air. One mysterious quality is displayed when an open beaker of liquid helium is suspended over another larger container of the substance. The helium in the upper container crawls up the side of the container and drops down into the lower vessel. The liquid shows an almost animal intelligence in seeking to join larger quantities of the same material.

Experiments have been conducted at Yale wherein containers of helium discharge into larger vessels, but never seem to empty. Measurements indicate that the smaller container will continue emptying itself for years. Thus the container of helium behaves like a bottomless, inexhaustible well.